

Characterization of Critical Thinking Indicators in Problem-Based Learning Online  
Discussions of Blended and Distance Undergraduate Environmental Science Students  
using the Community of Inquiry Model

by

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BSc (Honours), University of Victoria, 1990  
MSc, University of Victoria, 1993

A Dissertation Submitted in Partial Fulfillment  
of the Requirements for the Degree of

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University of Victoria

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## **Supervisory Committee**

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Dr. Tim Pelton, Department of Curriculum and Instruction  
**Supervisor**

Dr. Leslee Francis Pelton, Department of Curriculum and Instruction  
**Departmental Member**

Dr. John O. Anderson, Department of Educational Psychology & Leadership Studies  
**Outside Member**

## Abstract

### **Supervisory Committee**

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This mixed methods study compared distance and blended undergraduate environmental students at Royal Roads University (RRU) as they participated in online asynchronous PBL case discussion forums as part of an Ecotoxicology course. This study examined the differences between distance and blended teams in their activity, approaches, and levels of critical thinking in an online PBL activity. Critical thinking was evaluated using the cognitive presence indicators of the community of inquiry framework developed by Garrison, Anderson and Archer (2001). An organization indicator was added to the framework to capture posts that organized the discussion forum layout or the team and the distribution of work. The use of the organization indicator in the thread map analysis revealed that teams adopted one of two approaches to the online PBL activity, either an organic approach or an organizational scaffold approach. An open coding approach to content analysis of the posts was used to develop two coding schemes to capture the use of learning scaffolds and degree of online collaboration respectively. These coding schemes were used to compare scaffolding and collaboration behaviours of distance and blended students during the online PBL activity. The study found that whether teams used the online discussion forums or face-to-face discussion as their primary communication method influenced both the timing and the critical thinking content of the online discussion forums. Student moderators' choices influenced the structure and approach to the PBL activity, as well as the form of document assembly that was observed in the online discussion forums. The learning scaffolds coding scheme demonstrated that both distance and blended students were reading beyond the assigned reading list. Both distance and blended students appeared to develop

skills in identifying information gaps over the progression of the PBL case problems as their observable level of critical thinking remained consistent as the problem scaffolding was faded. Although both environmental and non-environmental work experience may be used to scaffold team learning, they are used differently. Online PBL is a good fit for the Royal Roads University Learning and Teaching Model and may be used to provide some consistency across blended and online course content.

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## List of Abbreviations

CLS	Collaboration and Learning Scaffolds
CofI	Community of inquiry model
DE	Distance education
FE-PBL	Final exam problem-based learning (the score on the PBL-like scenario portion of the final exam).
LS	Learning scaffold
LTM	Learning and teaching model
PBL	Problem-based learning
PBL-CT	Problem-based learning critical thinking score
RRU	Royal Roads University

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## Chapter 1

Problem-based learning (PBL) is a team-based learning method that allows students to learn and explore knowledge and concepts in the context of solving real-world problems (Barrows, 1996; Barrows, 2002; Hmelo-Silver, 2004). The goals of PBL are for students to develop flexible, transferable knowledge and self-motivation, as well as skills in collaboration, problem solving, and self-study (Hmelo-Silver, 2004). PBL can promote deeper approaches to learning by encouraging critical or higher order thinking skills such as researching, engaging critically with the course material, making linkages between research and previous knowledge and experience, and actively constructing knowledge (Ellis, Goodyear, Brilliant, & Prosser, 2007; Hmelo-Silver, 2004; Kanuka, 2005). PBL was originally designed with face-to-face team interactions in mind (Barrows, 1986); however, online technologies now exist that allow it to be applied in situations where students are studying remotely from both the instructor and each other (distance education) (Barrows, 2002), or in situations where face-to-face instruction is combined with online components (blended education).

Education can be provided in three general formats: distance education (DE), face-to-face education, or blended education. Distance education utilizes technologies such as the internet to provide two-way communication between teachers and students who are separated by distances (Bernard et al., 2004). In DE two-way communication may be synchronous which requires participants to be online at the same time (e.g. Skype); or asynchronous which allows participants to contribute in a time and place of their choosing (e.g. discussion forums). Face-to-face education encompasses situations in which the students and the teachers are in the same room, and working with each other face-to-face, while blended education combines facets of both DE and face-to-face education. Blended education features face-to-face classroom time combined with online elements that occur outside of class time. Similar to DE, the online elements of blended classes can be either synchronous or asynchronous. Comparisons between the different educational formats (usually distance versus face-to-face) were usually done to evaluate the relative efficacy of the formats with respect to student achievement, attitude and retention (Bernard et al., 2004).

As blended and distance education offerings become more common in the post-secondary sector, the question of how problem-based learning (PBL) can be adapted to the distance environment is being more closely considered (Barrows, 2002). With Royal Roads University's (RRU) emphasis on distance and blended learning, there is an institutional interest in online PBL, its scaffolding to support student learning, and its assessment (Royal Roads University, 2013b). This institutional interest combined with the instructor's anecdotal observations that distance and blended students behaved differently when completing an online PBL activity were the initial drivers for this study.

This study uses the community of inquiry (CofI) framework developed by Garrison, Anderson and Archer (2001) to support an examination of the similarities and differences in the critical thinking as well as some of the variables that impact its demonstration when distance and blended undergraduate environmental science students are engaged in online PBL using asynchronous discussion forums. Garrison and Anderson (2003) describe an online education experience as being made up of three intersecting parts – cognitive presence, teaching presence and social presence. Garrison's group developed the practical inquiry model to describe the process of critical inquiry (critical thinking). The practical inquiry model as described by Garrison et al. includes four phases for critical thinking: triggering, exploration, integration, and resolution (2001). Critical thinking as described by these phases and their behavioural indicators was used to define critical thinking in this study, and will be further elaborated on in chapter two.

This chapter introduces the educational context, including a description of the distance and blended Bachelor of Science (BSc) programs at RRU, and the data that suggested that distance and blended students behaved differently when challenged with an online PBL activity. The subsequent sections describe the purpose, the literature gaps that the study contributes to filling, and the research questions that guide the study. The final section of the chapter describes the instructional design and development of the Ecotoxicology course and its online PBL activity.

### **Educational context of the study**

RRU offers two multidisciplinary Bachelor of Science (BSc) programs: an Environmental Management offered primarily online, and a campus-based

Environmental Science program. The BSc in Environmental Management program (designated as the distance program in this study) combines an annual three-week residency period with distance education courses during the remainder of the year. During each of the three residencies, laboratory or fieldwork components of distance courses are taught, in conjunction with three condensed three-credit (36 hour) courses. Distance courses that include laboratory components immediately precede or follow a residency. The Environmental Management program also contains several business and policy courses that are not included in the BSc in Environmental Science program. The BSc in Environmental Science program (designated as the blended program in this study) is taught primarily face-to-face, but does contain some blended courses that include asynchronous online discussion forums or other DE elements. This program contains both laboratory and fieldwork components, as well as a nine-month major project as a capstone. The two BSc programs at RRU hold approximately 70% of the courses in common, including the Ecotoxicology course that is the context for this study.

Both of the RRU BSc programs are cohort-based with a strong emphasis on team work and collaboration (Royal Roads University, 2013b; See Appendix C for program learning outcomes). The social interactions that develop within the cohorts “support the conversational, dialogical, and, therefore, socially constructed nature of adult learning” (Royal Roads University, 2013b, p.21). These social interactions also help students to develop the necessary level of social comfort with one another so that they can successfully discuss course content (Garrison & Anderson, 2003). Garrison and Anderson (2003) note that for distance students

...consideration needs to be given to an initial face-to-face meeting of the group. This can have an accelerating effect on establishing social presence and can shift the group dynamics much more rapidly towards intellectually productive activities. Learning activities that may be more effectively or efficiently conducted in a face-to-face setting could also be scheduled at this time. Such blended approaches have strong advantages that go beyond social presence. The downside is, of course, the loss of freedom with regard to time and location. This may be a worthwhile trade-off (p. 54).

This is a benefit enjoyed by both distance and blended students at RRU (Guilar & Loring, 2008; Royal Roads University, 2013b). The strong social dynamic that develops in both distance and blended cohorts is thought to be the basis for the very high course and program completion rates reported by program faculty (Guilar & Loring, 2008)

At RRU the investigator teaches an Ecotoxicology course which features an online problem-based learning component. This fourteen week, 4.5 credit course occurs near the end of both programs of study, and is intended to allow students to integrate ideas from other courses with Ecotoxicology in an applied context. This course is offered in two formats: the first format delivers the instruction online at a distance with the laboratory taken face-to-face during residency, while the second format blends face-to-face classroom and laboratory instruction with the online PBL activity. All students in the Environmental Management program take the distance version of the course, while all students in the Environmental Science program take the blended version of the course. The current versions of the course include presentations, discussions, laboratory components, and an online PBL assignment that includes four linked cases. The laboratory component of the course is not part of the PBL activity, but does serve to familiarize students with some of the common laboratory practices of ecotoxicology such as enzyme assays and toxicity testing on protozoans and plants.

The PBL case activity unfolds as the course progresses, thus offering a concurrent opportunity for applied learning to support the theory that is being taught through the readings and online discussions for the distance group, and in the classroom for the blended group. The content of the course is updated annually, with the same course textbook and reading list used for the distance and blended cohorts in the same academic year. The PBL case activity accounts for one-third of the course work.

The Ecotoxicology course in both instructional formats has been taught by the investigator since 2000 with the exception of the 2001 and 2013 offerings of the blended course. Reading the discussion forums as the course instructor prior to the start of the study gave the investigator the impression that the distance and blended teams' discussions were different. The course underwent a major redesign in 2002 when the

online PBL case activity was added to both distance and blended versions of the course.

Although there is the possibility of bias in delivery as the investigator and the instructor are the same person within this study several steps were taken to minimize this problem. The instructor had read and participated in all the discussion forums as the courses were taking place, but the choice of the cohorts was not finalized nor was any analysis done until after the various cohorts had completed their programs and the ethical approvals were in place from both the University of Victoria (December 2011) and Royal Roads University (January 2012) (see Appendix A for copies of the certificates of ethical approval). This provided some distance between the instructor and investigator roles. Because the research represented a secondary use of information that was collected while the investigator was in a prior teaching role, a research agreement was also developed between RRU and the investigator to help to define what information could be used as part of the analysis. As a result of this dual role, the term instructor will be used when describing teaching and learning conditions in this study, while investigator will be used when describing the research in this document

Consistency between the distance and blended versions of the course was important for three reasons: to help minimize delivery bias (as previously discussed), to conform to university policy, and to allow for meaningful comparisons to be made between the distance and blended courses. Because the course carries the same designation (ENSC 407) in both the distance and blended programs, the university requires the course to be as similar as possible. As a result, the instructional materials for the matched distance and blended cohorts in this study (e.g. instructor's lecture notes) as well as the reading list and text book were the same. The same changes to the PBL activity as well as other course assignments and evaluations were made to both the distance and blended versions of the course that were offered in the same academic year. The scenario portion of the final exam was also identical for distance and blended cohorts taught in the same year. It is not uncommon due to scheduling that the distance and the blended offerings of the course overlap, making it easier for instructional materials and reading lists to remain synchronized. Both the distance and blended courses are evaluated using the same learning outcomes (see Appendix C).

The instructor's policy of providing extensive feedback on marked assignments and being available for contact via email, the course website, or by other means (face-to-face or telephone as appropriate) was also as similar as possible for both distance and blended students, which resulted in extensive student contact with both types of students. It is hoped that these steps would have minimized any potential delivery bias.

### **Purpose of this study**

The impetus for this study was the investigator's observation that the teams from the distance and blended cohorts appeared to approach the PBL problems and use the online discussion forums differently. The distance class seemed to be actually "discussing" the problems on the discussion forum while the blended class was treating the forum more like an information dump to allow the moderator to assemble the final document. This observation made the investigator wonder about what might be causing the observed differences.

The purpose of this mixed methods study was to examine the similarities and differences in the critical thinking exhibited by distance and blended undergraduate environmental science students during an online PBL activity in order to determine the best ways to support the learning of these students. This study also examined some of the emergent variables, such as moderator choices and scaffolding, which impact the demonstration of critical thinking when students are engaged in online PBL.

### **Why is this research significant?**

This research project is significant because it addresses several significant gaps in the PBL literature. Specifically, we need more PBL studies:

- *that examine PBL outside of the medical domain;*
- *go beyond comparing "traditional" lecture to PBL;*
- *that fully describe the problem typology and the type of PBL used;*
- *that compare a single type of DE with a face-to-face condition, and fully describe both conditions;*
- *that examine online PBL; and*
- *that examine the PBL scaffolding and its influence on critical thinking.*

The next sections will provide more information on these literature gaps.

### **PBL studies that examine PBL outside of the medical domain.**

The majority of the literature in PBL is concentrated in the medical education literature (Albanese & Mitchell, 1993; Dochy, Segers, Van Den Bossche, & Gijbels, 2003; Gijbels, Dochy, Van Den Bossche, & Segers, 2005; Newman, 2003; Strobel & van Barneveld, 2009; Walker & Leary, 2009; Vernon & Blake, 1993). While this is not a great surprise given that PBL has its roots in medical education, this narrow focus has limited PBL research and left other fields extrapolating results into substantively different contexts. For example, literature reviews and meta-analyses published since 2003 have sought to include studies that were based in areas outside of medical education but their authors have had difficulty locating such studies (e.g. Dochy et al., 2003; Gijbels et al., 2005; Jin & Bridges, 2016; Walker & Leary, 2009).

Walker and Leary's 2009 review suggests that "PBL may do best outside of medical education and allied health, when assessment [of the course material] is at the application rather than the conceptual level" (p.28). Other reviews (e.g. Gijbels et al., 2005) have come to similar conclusions based on the medical PBL literature. Given the multidisciplinary nature of Ecotoxicology and the applied nature of the Royal Roads University BSc programs and their typical assessments, this study may provide a helpful addition to the literature. Walker and Leary suggested that "A logical next step is to investigate why...disciplines outside the field of origin [medicine] are more efficacious homes for this kind of instruction" (2009, p. 28). This conclusion was based on a very small number of studies in disciplines outside of medicine that met the review inclusion criteria, but it suggests a literature gap may exist for studies in disciplines outside of medicine. Although this study neither makes comparisons to other disciplines nor formally addresses why PBL is a good fit for nonmedical disciplines, it is hoped that the study may help to shed some light on some factors that made PBL an effective instructional strategy in the Ecotoxicology course for both distance and blended students.

### **PBL studies that go beyond comparing “traditional” lecture to PBL.**

Although much of the literature centers on comparisons between PBL classes and traditional lecture classes to assess which is the more effective form of instruction (see e.g. Albanese & Mitchell, 1993; Dochy et al., 2003; Gijbels et al., 2005), this study departs from that path. The focus of this study is on examining how and why the distance and blended teams are both similar and different when engaged in the same sequence of online PBL case challenges conducted in asynchronous threaded discussion forums.

### **PBL studies that fully describe the problem typology and the type of PBL used.**

The recent meta-analysis by Walker and Leary (2009) noted that very few articles discuss or even name the type of problem used in the PBL situation under study (Walker & Leary, 2009). For example, both Jonassen and Hung (2008) and Walker and Leary (2009) note that there is a lack of information on the use of problem types other than the “diagnosis-solution” type that are common to medical education. As studies of PBL in medical education make up the vast majority of the PBL literature, there is a need for studies examining the use of PBL in other disciplines that may use other types of problems. The overall design of the PBL problems in the Ecotoxicology course has remained relatively constant over the years. The wording and some of the included scaffolds have been tweaked over time as issues with student understanding were identified. This study contributes to the literature by identifying the type of problems used in the course.

A wide variety of different but related approaches to instruction can fall under the heading of PBL. Barrows’ taxonomy for PBL (Barrows, 1986) is used to describe some of the PBL variations, but in most cases research papers do not elaborate on the PBL method being used or even name it (Barrows, 2002; Walker & Leary, 2009). The lack of information on how PBL is being applied in different studies makes interpretation and comparisons between studies difficult. Walker and Leary’s 2009 review noted that only five of 201 studies included in their analysis mentioned the type of PBL employed, and all five of these made use of the closed-loop method, which asks students to critique

their approach at the end of the problem (Barrows, 1986). This study makes use of the Problem-based method in which authentic problems are presented to small groups and free inquiry is required. The teachers or tutors may directly activate prior knowledge in exploration phase (Barrows, 1986). This method is very similar to the closed-loop method but does not require students to formally critique their approach to the problem at the end.

**PBL studies that compare a single type of DE with a face-to-face condition, and fully describe both conditions.**

In 2004 Bernard et al. conducted a meta-analysis that reviewed 232 studies published between 1985 and 2002 comparing online and face-to-face classes with respect to student attitude, achievement, and retention using effect size statistics (Bernard et al., 2004). Because the online category included both synchronous and asynchronous forms of online discussion placed within various methods of DE, comparisons between the studies were challenging (Bernard et al., 2004). One problem noted by this research group was that in many cases the features of the studies used for the analysis were poorly described – especially with respect to the conditions in the face-to-face classroom (Bernard et al., 2004). This problem appears to be due to the assumption that everyone ‘knows’ what a traditional face-to-face classroom is. However, given the breadth of teaching styles and philosophies used by face-to-face instructors, it seems unlikely that they are all doing the same thing even though they may be using the same medium to teach (face-to-face communication). As Bernard et al. point out

often, authors went to extraordinary lengths to describe the DE [distance education] condition, only to say that it was being compared with a “classroom condition.” If we cannot discern what a DE condition is being compared with, it is very difficult to come to any conclusion as to what is meant by an effect size characterizing differences (2004, p. 407).

It is interesting that many of the same literature gaps that exist for the study of PBL also exist for the study of face-to-face and distance learning comparisons. For

example, a lack of rich description of both conditions, differences in the assessment of both groups, variation in investigators, and a lack of consistency in what is being described as “distance education”. This study contributes to filling the literature gap by providing a rich description of the two comparison conditions of blended and distance forms of the PBL.

### **PBL studies that examine online PBL.**

Although most applications of PBL are in a face-to-face format (McLinden, McCall, Hinton & Weston, 2006), as blended and distance education offerings become more common in the post-secondary sector, the question of how problem-based learning can be adapted to the distance environment is being more closely considered (Barrows, 2002). A recent meta-analysis by Bernard et al. (2004) comparing distance and face-to-face classes with respect to student attitude, achievement, and retention did note that the inclusion of asynchronous PBL is a “strong predictor in favor of the DE [distance education] condition” (Bernard et al., 2004, p. 412) compared to a “standard” face-to-face class that doesn’t include PBL. However, they also cautioned that this conclusion was based on only a small number of studies included in the review, and that the PBL component took a variety of different forms. The authors further suggested that the increased communication opportunities and collaborative working style associated with PBL were responsible for the positive effects observed on student achievement, attitude and retention when compared to traditional classrooms (Bernard et al., 2004). The Bernard et al. (2004) meta-analysis did not compare distance and face-to-face classes that both included a PBL activity, or distance and blended classes that both included an online PBL activity, which indicates a literature gap. This study examines differences between the observed levels of critical thinking by distance and blended students during a PBL activity as well as their achievement on the PBL-like scenario portion of the final exam. This study also represents a chance to look at how asynchronous online PBL discussions proceed and the scaffolding structures that may be needed to support distance and blended students’ success when using online PBL.

### **PBL studies that examine the PBL scaffolding and its influence on critical thinking.**

One issue that arises in the literature with applying PBL to fields outside of medicine is that the original approach was designed for *medical students*. No direct instruction was used in the original McMaster model (Barrows, 1996), and medical students already have an undergraduate degree. Arguably fewer learning supports (scaffolds) are needed for this group because the instructional format was effectively designed for graduate students (i.e. post bachelor's degree) in a high stakes environment. Based on his work with teachers and middle school students, Belland (2016) pointed out "for students to be motivated, support is needed. And such support enhances cognitive learning." (Integrating motivational and cognitive perspectives with scaffolding section, para 1).

Similar to other researchers (e.g. Belland, 2016; Hmelo-Silver, 2004; Hmelo-Silver, Duncan & Chin, 2007), the investigator's experience indicates that undergraduates benefit from some scaffolding – either in the form of "just-in-time" direct instruction or in the form of hard scaffolds within the PBL problems themselves. Strobel and van Barneveld (2009) suggested that the

focus [of PBL research] should shift from researching the effectiveness of PBL versus traditional learning, and should refocus on studying the differences in effectiveness of supporting structures to find optimal scaffolding, coaching, and modeling strategies for successful facilitation of PBL (p.55).

This study will look at the effect of different types of learning scaffolds on the critical thinking of undergraduate science students as expressed in online PBL case discussion forums.

### **Key research questions**

As noted above, this research study will contribute information to some of the identified literature gaps just by focussing on an undergraduate science course, as well as by describing the type of PBL, the nature of the problems, and the form of distance education used. In addition to this study examining critical thinking indicators and the

process of the online PBL discussion, the comparison groups (distance cohorts versus blended cohorts) have different supporting structures, which will be examined for their impact on the use of critical thinking indicators.

The research questions guiding this study are:

1. How does the online asynchronous PBL forum activity of distance and blended students differ? How does this activity change over time?
2. In what ways do the levels of critical thinking observed in students from distance and blended courses differ in similar online PBL situations? What elements influence this?
3. How do the observed levels of critical thinking change as students from distance and blended cohorts progress through a sequence of four PBL cases in the Ecotoxicology course?
4. Is there evidence that student posts containing critical thinking indicators affect the participation of students in following posts?
5. Is critical thinking more apparent in subjects where students have more prior work experience? How do students with more work experience use that experience within the group discussion? Do they use it to scaffold the critical thinking of their group?
6. What types of scaffolds are used most by students? Are there differences in use across students from distance and blended courses? Is there evidence in the discussion posts that the scaffolds used by students support their critical thinking?

### **Instructional Design of the Ecotoxicology Course**

The instructor's initial experience of teaching the Ecotoxicology course was not positive. The course was extremely content-heavy, and because the focus of the course was supposed to be on the application of theory in the real world, an instructional tension was created. The students couldn't understand the applications without understanding the underlying theory, and there wasn't enough instructional time to teach both the necessary theory and its application. To address this tension, the

instructor decided to redevelop the course with several goals in mind: to streamline the amount of theory; to concentrate on fewer applications; to encourage students to read and research in the literature; and to more obviously connect the practical application of the laboratory exercises to the rest of the course (and the programs).

The instructor initially chose to include an online asynchronous discussion component because its inclusion in an earlier microbiology course was a successful experience as evidenced by positive mentions in both formal and informal student feedback. In that course, students were provided with short science articles to read, followed by one to three open-ended questions to discuss in the online discussion forum. This exercise was used with both distance and blended students, and provided an opportunity for students to connect theory and practice in microbiology. The instructor observed that the use of the online discussions increased student confidence in sharing their ideas as quieter students participated fully online and began to also participate in face-to-face class discussions. The online discussions also provided students with time to think in a way that was not possible in a face-to-face classroom or synchronous online discussion. It was only later that the investigator learned that her pragmatic instructional design choices that were based on personal observations were supported by the education literature (e.g. Meyer, 2003; Tiene, 2000). The instructor wanted to build on this positive learning experience with online discussions by offering a more challenging online component in the Ecotoxicology course.

One of the instructional designers at RRU suggested that PBL case studies might be a possibility to consider. This suggestion led the instructor to consider some of the possible alignments between PBL and both the course redesign goals, and the learning and teaching culture of RRU. The features of this culture were later articulated as the RRU Learning and Teaching Model (LTM) (Royal Roads University, 2013b). PBL and the learning and teaching culture both emphasized team work, student-centered learning, the development of flexible, transferable knowledge, motivation and skills in collaboration, problem-solving and self-study (Barrows, 1996; Hmelo-Silver, 2004; Royal Roads University, 2013b). The instructor felt that the use of the authentic problems that characterize PBL would provide the chance to anchor the learning of Ecotoxicology theory in real world applications. It was also hoped that the problems

would interest students and encourage them to engage in self-directed research, discussion and critical reflection on the literature in the field, and to take personal responsibility for their learning. Although PBL usually takes place in face-to-face teams (McLinden, McCall, Hinton, & Weston, 2006), the instructor felt that it could be adapted for use in the online discussion environment. An online environment provides several advantages to the PBL process: a permanent written record of the discussion is created, ideas can be revisited over time, and time is available for personal research and reflection. In a face-to-face discussion, most of the discussion is carried by those who are able to think and articulate their understandings quickly, and the discussion may move on before everyone has a chance to contribute their ideas (Meyer, 2003; Stromso et al., 2007; Tiene, 2000). The investigator's experience has been that the online PBL discussions provide a valuable window on students' problem-solving, theoretical understanding and teamwork.

In order to include PBL case problems as an online component of the course, appropriate problems needed to be found or developed. The instructor reviewed a large number of real world problems including various oil and chemical spills (e.g. Exxon Valdez spill) as well as industrial accidents (e.g. Chernobyl), each of which would potentially encourage students to investigate a few of the key concepts of the course. However, none of the problems would lead students to investigate all the key concepts, and a "solution" to the reviewed problems was available in the literature. The instructor decided to combine elements from many different cases into a sequence of four linked PBL case problems. The problems were designed around a fictitious community that contained various industries. Pairs of student moderators are used for each case to allow them to support each other as they develop moderation skills such as guiding the flow of a discussion, helping to establish expectations and timelines, as well as helping make sure everyone is heard. At the conclusion of each PBL case problem, the team was required to submit a report summarizing their solution for that particular problem. As in the real world, decisions that the team made during the earlier case problems determined some of the choices that were available to the team in the latter case problems, and results in a variety of possible solutions. The students only see the next

case problem after the completion of the previous case, so their decisions about the solution of the current case are not influenced by where the problem is going next.

At the time the course was redesigned, the instructor believed that students needed guidance in the tools that they were expected to use prior to them having to use them, and that the students would require guidance to transition to success with using PBL. Although the PBL literature includes studies that were based on entirely unguided PBL, there is other literature that indicates that unguided PBL would not be useful for undergraduate students with no previous experience (Kirschner, Sweller and Clark, 2006). Initially, the backing for the idea that instructor support would be necessary for student success came from the description of teaching presence in the CofI model (Garrison et al., 2001). Additional support for the instructional design choice was later provided by Jonassen's observation that

...because PBL represents a significant shift in learning for most students, they require support in adapting their learning methods. We cannot assume that learners are naturally skilled in problem solving, especially complex and ill-structured problems such as those required in most PBL programs (Jonassen, 2011 p. 96)

Part of the goal of both PBL and the RRU LTM is for students to become independent learners. It was hoped that students would require less support to successfully address the PBL cases as they became more familiar with evaluating their knowledge gaps and finding research materials. As a result, PBL case one contained many embedded scaffolds to guide what the final report should contain and the number of scaffolds included in the subsequent PBL cases decreased from case one to four.

### **Concluding remarks**

The initial driver for this study was the investigator's observations that the teams from the distance and blended cohorts appeared to approach the PBL problems and use the online discussion forums differently. This study represents an attempt to focus on critical thinking as operationally defined by the community of inquiry (CofI) cognitive presence indicators exhibited by both distance and blended program students in online asynchronous PBL discussions and the various influences that might impact it.

Chapter two reviews the literature on PBL, distance education, PBL in the online asynchronous environment, and critical thinking in discussion posts. Chapter two also introduces the Cofl cognitive, teaching and social presence indicators. Chapter three to five present the methods, results and discussion. Chapter six comments on the implications of the research, as well as how the results address the research questions. It also discusses the limitations of the study, and possible future directions for research.

## **Chapter 2 Literature Review**

While teaching the Ecotoxicology course over many years, the investigator had observed that distance and blended environmental science undergraduate students behaved differently in the asynchronous online discussion forums that were used for the team-based PBL cases. The investigator was interested in the similarities and differences in the approach to the PBL activity and the evidence of critical thinking in the posts of distance and blended teams. The RRU Learning and Teaching model (LTM) has a strong emphasis on distance and blended educational approaches (Royal Roads University, 2013b). As a result of the LTM's emphasis, the university and investigator have a shared interest in research supporting the use of online PBL, developing critical thinking skills in distance and blended students, and “unpacking” what is happening in the distance and blended teams as they undertake PBL.

This literature review will define PBL as used in this study and highlight some of the practical developments in PBL in the past couple of decades. This will be followed by a review and discussion of some of the possible variations of the PBL method, the characteristics of PBL problems, and the different types of scaffolds to support student learning. Distance education and adapting PBL to distance education will be discussed to provide context to the online PBL activity that is the focus of the study. Critical thinking as a process and product, and the use of online discussion forums to teach and assess critical thinking will then be introduced. The final portion of the literature review introduces the Community of Inquiry (CofI) model that will be used in the content analysis of this study to examine critical thinking (cognitive indicators) and the variables that influence how critical thinking can be observed in online discussion forums.

### **What is PBL?**

This section begins by exploring what PBL is and defining how the term will be used throughout this study. This is an important place to begin as there is a wide variation in the application of this term in the literature. The second part of this section will discuss learning to think like an expert (i.e. developing expertise in a field) because PBL is thought to help students to connect facts, principles and applications.

### **Working definition of PBL.**

PBL is a team-based learning method that focuses students on solving real-world problems (Barrows, 1996; Barrows, 2002; Hmelo-Silver, 2004). It can be considered as a “thinking apprenticeship”; a way to help students to think in the ways that a professional in the field of study would. Although PBL has been in use in medical schools for over fifty years (starting in McMaster University; Barrows, 1996), it is only within the last twenty years that it has been widely adopted by other disciplines, including law, engineering, business, education and social work (Albanese & Mitchell, 1993; Gijbels et al., 2005; Major & Palmer, 2001; Savery & Duffy, 1996). PBL is very similar to inquiry-based learning (IBL), which can be defined as “a flexible and active process of learning, characterized by questions, investigations, explorations, applications and synthesis” (Brown, 2003, p.31).

IBL may or may not be considered as distinct from PBL (e.g., Hmelo-Silver et al., 2007). Both use authentic problems as learning organizers, and emphasize collaborative learning, cognitive engagement, developing evidence-based explanations, and communication of ideas (Hmelo-Silver et al., 2007). Both PBL and IBL share the goals of students developing flexible, transferable knowledge, motivation and skills in collaboration, problem solving, and self-study (Hmelo-Silver, 2004). Some authors consider the difference between PBL and IBL to be in the role of the facilitator or tutor. In IBL, the tutor acts as both a role model for inquiry (i.e. encouraging critical thinking, and questioning skills) *and* as an information resource for the problem (e.g. Edelson et al., 1999; Hmelo-Silver et al., 2007). In PBL, the tutor facilitates the group process, and models critical thinking and questioning approaches but does not provide information about the problem (Barrows, 1986; Barrows, 1996; Koschmann, 1994; Koschmann, Myers, Feltovich, & Barrows, 1994; Savery, 2006). However the distinction between IBL and PBL isn’t clearly marked because it is likely that it will be necessary for the tutor to support students with information resources initially, and remove this support over time as the students gain confidence in their abilities to locate and select their own resources (Barrows, 2002; Hmelo-Silver, 2004; Hmelo-Silver et al., 2007). As a result of this initial need for scaffolding, both IBL and PBL were considered under the umbrella of PBL in this study.

PBL is a group-based constructivist approach to knowledge building and requires context to facilitate learning (Savery & Duffy, 1996). In PBL, the actual solution that results is secondary to the team-based learning process. The PBL approach “assumes that students will master content while solving a meaningful problem” (Jonassen, 2011, p. 101). A PBL activity begins with the problem being presented to the students. They brainstorm their approach, decide what facts or skills that they need to approach the problem, do some self-directed research, then share what they have learned with the group, and critically assess their knowledge to support the identification of their next step. This process may go through several iterations depending on the time frame for the exercise and the complexity of the problem (Barrows, 1996; Dahlgren & Oberg, 2001; Koschmann et al., 1994). Similar to the observations of other authors (Guilar & Loring, 2008; Hmelo-Silver, 2004; Hmelo-Silver et al., 2007), the investigator found that in practice, PBL promoted a dialogue between peers that led to a deeper understanding of the applied concepts, supported teamwork and the formation of learning communities, as well as encouraged students to take personal responsibility for their own learning and the learning of their team. In the context of this study PBL also enabled the learning of Ecotoxicology to be firmly anchored within the reality of life in the world, thus encouraging the students to be engaged in self-reflection and practical applications of their learning.

### **Learning to think like an expert.**

The thinking and problem solving approaches used by novice learners and experts are different. PBL is thought to be a way to help to bridge the gap as novices develop into experts. PBL can be described as a “thinking apprenticeship” or a way to help students learn to think like the experts in the field to prepare them to enter the workplace. PBL also encourages students to work with the tools, techniques, and vocabulary of their chosen field.

Research in cognitive psychology has demonstrated that experts possess extensive knowledge of their field and knowhow to flexibly use that knowledge to solve problems (Gijbels et al., 2005). That is, they are able to use data-driven strategies to quickly recognize patterns that they have already seen and apply the most likely

solution to a new problem based on that previous experience (Hmelo-Silver, 2004). Students are often unsuccessful with data-driven problem solving because students lack either the extensive organized content knowledge or the ability to activate the knowledge that would be necessary to apply it to novel situations. A commonly used unsuccessful strategy is memorizing as much random information as possible in hopes of quickly building their internal database. The problem is that memorizing random facts makes it difficult not only to connect new ideas to previously learned information but also to activate the new knowledge so it can be applied to solving novel problems (Koschmann et al., 1994).

PBL is thought to train students to think like an expert by using the problems to combine the learning of the facts, concepts and principles with consideration of their applications. This combination allows the students to make more robust connections between information and its application, and makes it more likely that students will be able to activate this knowledge when confronted with a new problem.

Using PBL, novice students learn to apply hypothesis-driven reasoning, in which students generate hypotheses about the solution to the problem, test them through research to determine what information does or does not support hypotheses, then critique the hypotheses and research within the group, and accept them and move on or develop a new hypothesis (Hmelo-Silver, 2004). These hypotheses can be formal or informal. In the Ecotoxicology PBL activity, the hypotheses are informal and students may refer to them as knowledge gaps or “things to find out” (Bev, 2010 distance learner). By cycling through the hypothesis generation and testing process, students practice defining the problem, activating their knowledge and refining strategies that can be more easily transferred to new problems (Hmelo-Silver, 2004). Hypothesis-driven strategies have been shown to allow PBL students to more easily transfer the strategy to new problems, and to generate more coherent explanations that incorporate basic knowledge than students without PBL experience who are trying to use data-driven reasoning (Hmelo-Silver, 2004). As such, hypothesis-driven reasoning is considered a mechanism for learning (a way to develop the extensive organized internal database required for both expertise and the use of data-driven reasoning) (Hmelo-Silver, 2004).

Another aspect of learning to think like an expert is the process of enculturation. Students need to learn to work using the methods and vocabulary of their chosen field. Solving real life problems that reflect the nature and requirements of the profession that the student is going to enter “helps them not only feel prepared to share their knowledge and expertise in public forums and work effectively in their profession, but also to identify themselves as scholars and contributing members of the community of practice” (Dunlap, 2006b, p. 39).

The Ecotoxicology PBL case activities require students to not only identify their knowledge gaps, and determine how to fill them. This helps student to not only develop the organized knowledge base characteristic of developing expertise, but also to use the vocabulary and tools of the profession they are planning to enter. In addition, by using online PBL, students develop confidence and expertise in online learning and collaboration which are skills that are becoming increasingly important in the workplace.

### **Practical Developments in PBL**

Although McMaster University Faculty of Health Sciences Medical School implemented their PBL curriculum in 1969 with its first graduating class in 1972 (Barrows, 1996), we focus on the practical developments in PBL since 1993. This date was chosen as the start for our literature review of PBL because the review papers published in 1993 examined the work published between 1972 and 1992, and these reviews represent some of the most cited literature in this field (e.g., Albanese & Mitchell, 1993; Vernon & Blake, 1993). Marilla Svinicki commented that research on innovations in education typically follows an evolutionary pathway from “it works”, through “it also works here”, followed by critique of where it doesn’t work, and then finally investigation of the mechanics of exactly how and why it works, and under what conditions (Svinicki, 2007).

This section will follow the PBL literature along the pathway described by Svinicki since 1993. The literature on PBL published in 1993 was largely of the form “it works” and studies since 1993 seem to be mostly at the stage of “it also works here” with the movement from medical education into other fields. In other respects, the field is

definitely moving into both a critique phase as well as toward a more comprehensive investigation of exactly how and why it works.

### **It works.**

The 1993 review paper by Albanese and Mitchell, and the meta-analysis by Vernon and Blake are two of the most cited papers in the PBL literature and both are comparisons between PBL and traditional classroom instruction in medical education. Albanese and Mitchell's 1993 paper, *Problem-based learning: A review of literature on its outcomes and implementation issues*, was a meta-analysis of medical education literature between 1972-1992 that assessed the effectiveness of PBL based on a number of different outcome variables, ranging from basic science knowledge and clinical performance through study behaviours, and perceptions of both faculty and students. It is one of the most cited papers in the PBL field. They pointed out some of the difficulties inherent in making comparisons between studies including the issue of defining exactly what PBL and the "traditional" comparison class might be. They were cautiously optimistic about PBL, concluding that there was a slight trend for PBL students to be better in their clinical performance, but slightly worse on basic sciences performance. They highlighted that the results in these categories were very heterogeneous and proposed that some of the variability in the results could be due to differences in how PBL was implemented in the different research studies included in the review. They also noted that both faculty and students found it a more challenging and enjoyable form of education (Albanese & Mitchell, 1993). Vernon and Blake (1993) conducted a meta-analysis using most of the same source material used by Albanese and Mitchell (1993), and came to similar conclusions – that PBL was better for some variables and worse for others as compared to traditional classes, and that students generally found it more enjoyable. Both these reviews are very much part of the "it works" literature and PBL was treated as a single independent variable. Both groups of authors were cautiously optimistic about PBL, and called for further research to support both the theory and practice of PBL (Albanese & Mitchell, 1993; Vernon & Blake, 1993).

In 1996 Woodward conducted a narrative review exploring the research agenda of PBL (Woodward, 1996). Woodward noted that comparing PBL and traditional

programs using licensing or similar benchmark exam results is difficult because of the presence of confounding variables such as programs at different institutions having differing admissions criteria, typical clinical placements, and philosophies of care that could impact the results of the comparison (1996). Woodward's review is useful as it emphasized the development of group skills and interpersonal learning as an area of research that had not yet been looked at closely and mentions that "we should not discount the ability of bright people to learn what they need to know despite of any curriculum" (Woodward, 1996, p. 93). This important cautionary statement is echoed by some other authors during the critique phase of the PBL literature evolution (e.g. Albanese, 2000). The variety of methods used for PBL noted by the reviewers in this section also highlighted the need to define PBL and describe how it is implemented in research studies.

#### **Defining PBL and movement into nonmedical disciplines.**

The oft-cited review by Howard Barrows, *Problem-based learning in medicine and beyond: A brief overview* (1996), described the characteristics of the McMaster approach to PBL. These characteristics include that: the learning is student-centered and occurs in small groups; the teachers are facilitators; the problems form the organizing focus and stimulus for learning; the problems serve to develop discipline-specific problem-solving skills; and that new information is acquired through self-directed learning (Barrows, 1996). This paper is a significant addition to the literature because these characteristics are often taken as a definition of PBL by other authors (especially in inclusion criteria for review papers). Earlier work by Barrows included a published taxonomy of PBL methods which provides a useful starting point when discussing studies that may have used different forms of PBL (Barrows, 1986). The 1996 Barrows paper is also significant because it discusses the goals of PBL education as well as some of the issues that can enhance or inhibit the realization of those goals. Finally, Barrows discusses some work on using PBL with high school teachers and students, illustrating some of the movement of PBL out of medicine and into other contexts that was starting to occur (Barrows, 1996). This is indicative of the "it works here too" stage of the educational evolution (Svinicki, 2007) of PBL. With respect to

academic discipline, this stage is still ongoing. Even more recent review papers (e.g. Strobel & van Barneveld, 2009; Walker & Leary, 2009) had goals of including more research that was outside of medicine and medical education, but had challenges in locating them. This will be discussed further in the sub-section on opening the black box of PBL.

### **Critique phase.**

Svinicki (2007) noted that the study of educational interventions eventually reaches the critique phase in which investigators become more interested in questions about what does and doesn't work, and why. This phase of the literature examines comparisons between PBL and traditional classroom instruction with respect to effect sizes needed to show differences as well as considerations of variables that may impact the results of these comparisons. The year 2000 could be considered to be the beginning of the critique phase for PBL in medical education. During this year, three key papers were published by Colliver (2000), Albanese (2000) and Norman & Schmidt (2000).

Colliver's review included medical education studies from 1992-1998 that compared PBL and traditional classes between either different curriculum tracks at the same institution or a PBL curriculum at one school with a traditional curriculum at a second school (Colliver, 2000). This study brought up the question of how large an effect size is required to indicate a significant difference between PBL and the comparison condition into the literature (Colliver, 2000). Based on his analysis, Colliver concluded that there was "no convincing evidence for the effectiveness of PBL, at least not the magnitude of effectiveness that would be hoped for with a major curriculum intervention" (Colliver, 2000). Colliver advocated for a very large effect size of 1.00 (Colliver, 2000) based on the work of Bloom who found effect sizes of 2.00 when comparing one-to-one tutoring (held up as the best learning condition available) with standard classroom instruction in children in grade four, five and eight (Bloom, 1984). Bloom had noted that a number of variables that affect student achievement (including: reinforcement, corrective feedback, student participation, time on task, cooperative learning, higher order questioning, etc.;1984), had individual effect sizes with respect to

student achievement scores of between 0.3 and 1.00 (Bloom, 1984). Bloom noted that the effect sizes for the various interventions based on these variables are not necessarily additive. For instance some of these interventions require a considerable investment of time, while others do not. In addition, the interventions are variously focussed on the learner, the teacher, the peer group or the instructional materials (Bloom, 1984). Thus, although it would appear that many of these individual interventions are potentially included in a PBL tutorial environment, it does not necessarily mean that comparing PBL to a conventional curriculum will show an effect size as large as Colliver is suggesting.

Another issue that arises is the problem of a ceiling effect in most studies. Albanese addresses this limitation in his 2000 response to Colliver's analysis and its conclusions titled *Problem-based learning: why curricula are likely to show little effect on knowledge and clinical skills* (Albanese, 2000). In an echo of Woodward (1996), Albanese (2000) points out medical students are demonstrated high achievers who have been selected based on a rigorous, competitive process, and who are under pressure to remain high achievers or lose their place in the program. This would seem to generate a problem – there is a limit to how much higher the top scores can become in response to the PBL treatment -- i.e., a ceiling effect (Albanese, 2000). It is therefore reasonable to ask how large an effect size is necessary for an intervention to have practical value. Albanese points out that

if only effect sizes of 0.80 or greater were considered to be of practical value, over half the psychological, educational and behavioural treatment literature and a number of drug therapies in common use (chemotherapy for breast cancer) would have been dismissed (Albanese, 2000, p.731).

In a similar vein, effect sizes are likely to be small (0.3 or below), especially under conditions where numerous extraneous variables cannot be controlled (Cohen, 1988; Lipsey et al., 2012) as is the case in studies that do not use experimental designs. It would be useful, therefore, to have access to more studies on PBL from fields outside of medicine to determine if the effect sizes that are observed are similar or different from what is observed for medical students, and if a ceiling effect would still be observed. Additionally, since there are various components to learning that are rolled into the

variable of a PBL intervention (such as levels of reinforcement, corrective feedback, student participation, time on task, cooperative learning skills, higher order questioning skills, self-directed learning skills, etc.) it would be useful to pull the process of PBL apart to a greater degree to determine the individual effects of these variables and how they impact each other.

Norman and Schmidt's response to Colliver (2000) outlines three main reasons that they feel curriculum level trials of PBL versus traditional class comparisons are ineffective in showing a difference in achievement between the two groups (Norman & Schmidt, 2000). Firstly, educational trials are not blinded (and typically not truly experimental) interventions – they are impacted by variables such as greater or lesser enthusiasm by either group (e.g. the control group may try harder, or the treatment group may be more excited about it) (Norman & Schmidt, 2000). Even if the students were to be randomly assigned, the lack of a true blinded intervention would confound the results because students would be aware of whether they were in a traditional or PBL class (the Hawthorne effect). Secondly, there was no achievement outcome that could be measured independently from the student's academic success in these studies (Norman & Schmidt, 2000). For example as Woodward (1996) and Albanese (2000) pointed out, medical students have been selected for their ability to succeed academically. When faced with high stakes exams such as the National Board of Medical Education licensing exam, a common achievement outcome used in the studies, students are going to use whatever strategies that they can to pass (Norman & Schmidt, 2000). This means that PBL students may not use purely PBL methods to study and pass these exams and, therefore, achievement outcomes on such assessments may not be just a result of the PBL intervention. Likewise, non-PBL students may use a variety of approaches to achieve success, including the use of PBL-like problems to study. Finally, PBL is not a uniform intervention – it is applied in different ways in different programs – in some programs a PBL initiative might be a small part of a single course within a program while in others, the entire curriculum is based on PBL (Edens, 2000). Even among curriculum level comparisons, many of the comparisons between lecture-based instruction and PBL instruction are studies in which a program or course is examined “before and after” PBL is instituted (Albanese

& Mitchell, 1993). That is, there is a temporal component to the comparison. This presents two major difficulties in using these studies to try to tease out the effects of PBL. The first is that any number of confounding variables may have changed over the same period (Albanese & Mitchell, 1993). For example, investigators may have changed, other curriculum or assessment changes may have occurred, transfer agreements for students entering the program may have changed, etc. Even if the temporal problem is not present due to the comparison occurring between simultaneously offered PBL and traditional lecture tracks in the same program, the definition of what the “traditional lecture” is may not be consistent from study to study either. Many lecturers include active learning elements in the traditional lecture (Albanese & Mitchell, 1993), which may make it less obviously different from PBL currently than it may have been for earlier classes, which will confound the comparison.

Variables in the PBL approach itself may also stem from differences in the problems, and in the way the problems are directed. Some PBL problems are presented in the form of a complete case with a summary of the facts that are needed to solve the problem (Barrows, 1986; Barrows, 2002). These types of problems are sometimes used to allow the exploration of background knowledge without simultaneously exploring the application of that knowledge (Margetson, 1998) – for example, to learn about the respiratory system without exploring treatment options for emphysema. Other PBL problems are presented in a less structured way – that is, facts need to be assembled to determine the context and approach that the students will take to the problem (Barrows, 1986; Barrows, 2002). These more ill-structured problems tend to be presented more as one would expect a real professional problem to be – a limited amount of information is initially available and one is expected to learn the background material and how to apply that information simultaneously as the problem evolves (Margetson, 1998). For example, a patient presents with difficulty in breathing. In this case, the student may be expected to learn about the respiratory system and emphysema while also learning about how to clinically manage this condition. This is considered to be an optimal strategy for allowing transfer of the information and skills learned to new problems (Norman & Schmidt, 2000). Still other problems may be presented as falling along a spectrum between these two options (Barrows, 1986). The results of PBL can also be

impacted by how much information or resources are provided, the degree to which feedback or group processes are encouraged as well as facilitator variables such as how directive the facilitator is (both too much and too little will negatively affect the process) (Albanese & Mitchell, 1993; Barrows, 1986; Barrows, 1996; Barrows, 2002).

The critique phase of PBL research is still ongoing but the work of Colliver (2000), Albanese (2000), and Norman & Schmidt (2000) moved PBL research into several important directions. These papers opened the discussion on the magnitude of effect size, recognized that PBL is not a single uniform variable. These papers also highlighted that different forms of PBL and PBL problem presentations may impact comparisons between PBL and traditional classes, and finally that strategies that PBL and traditional classroom students use may not be as distinctive as expected when measuring academic success in a high stakes conditions.

### **Starting to open the PBL “black box”.**

The PBL research since 2000 that has started to move towards examining the mechanics of what works within PBL, rather than simply comparing PBL to non-PBL situations. There is also interest in how the various variables, such as the discipline of study, PBL method and problem type, that may be used in PBL activities or curriculum come together to make a successful educational intervention (or not) in a particular context.

From 2003 - 2005, a number of reviews and meta-analyses were published that attempted to examine how PBL impacts learning. In 2003 the first pilot systematic review of PBL’s effectiveness using the Campbell Collaboration protocol (Campbell Collaboration, 2017) was published by Newman (2003). This review of curriculum level PBL was based on the use of twelve experimental or quasi-experimental controlled studies that were screened from the reference lists of previously published reviews. This review highlighted the need for more comprehensive reporting of published studies – including better descriptions of both the “PBL” and the “traditional” comparison condition used. Newman reported a negative effect of PBL versus traditional instruction on accumulation of knowledge, but noted that this was based on the use of the multiple-choice NBME part 1 exam as the benchmark (Newman, 2003). While the conclusion of

a negative effect of PBL on the accumulation of knowledge is not out of line with previous reviews, the methods used for this review have sparked a lot of commentary, especially the use of only controlled experimental and quasi-experimental studies in the analysis. Commentaries by Farrow and Norman (2003) as well as Dolmans (2003) indicated that while they agreed with Newman's conclusion about the need for more detailed reporting in studies, they took severe issue with the lack of discussion about the use of the assessment method (Dolmans, 2003; Farrow & Norman, 2003) as well as the assumption that "randomised experiments are the only sort that yield trustworthy or 'hard' evidence" (Dolmans, 2003, p. 1129). Although the implication of Newman's method that only randomized experimental data is worthwhile evidence seems problematic, the fact that this review has encouraged discussion of some of these issues makes it a useful addition to the literature.

Dochy et al. (2003) conducted a meta-analysis to look at the effects of PBL on knowledge acquisition (e.g., facts and meanings of concepts) versus skills (the application of knowledge). They included empirical studies from 1997-2002. They observed a positive effect of PBL versus traditional instruction for student scores on skills assessment, which is considered to be of practical significance based on effect size, but a small negative effect (not significant) on knowledge assessments. They further evaluated some potential moderators of PBL effects and found that the "more an instrument is capable of evaluating the skills of the student, the larger the ascertained effect of PBL" (Dochy et al., 2003, p. 550). This review posted similar conclusions to the 1993 reviews but with greater detail on the moderating effects.

The work of Dochy et al. (2003) was furthered by a meta-analysis focused on assessment in 2005 by Gijbels et al. who reviewed 39 studies in medical education using Sugrue's (1995) theory of problem-solving as a theoretical framework (Gijbels et al., 2005). In this framework, problem-solving results from the interactions between knowledge structures, meta-cognitive functions and motivation. The knowledge domain can be divided into three levels – level one is knowledge of concepts, level two is procedural knowledge (the principles that link the concepts), while level three is the application of principles and concepts to actual conditions. Level two and three are considered to be indicative of expertise in a field because experts have access to a

“well-structured network of concepts and principles” (Gijbels et al., 2005, p. 30) and know how to apply them. In the Gijbels et al. (2005) review, PBL and traditional students were compared using the three levels of the NBME examination as the evaluation points. The PBL group scored significantly better (effect size of 0.8) on the level two exam performance (corresponds to level two knowledge construction) and better (effect size of 0.34), but not significantly so, on the level three exam (Gijbels et al., 2005). As the NBME level 3 exam is the final licensing exam for American physicians, the comparison between PBL and ‘traditional lecture’ may be confounded somewhat by the high stakes attached to this assessment. This is in agreement with the conclusion of Dochy et al. (2003) that evaluations which better reflect the learning that occurs in PBL will show greater effects when PBL students are compared to traditional students. In addition, Gijbels et al. concluded the results were indicative of an accelerated move towards expertise (2005). This study is only one example of how the study of PBL is starting to move toward an analysis of what is occurring during the learning of PBL.

Walker and Leary's (2009) meta-analysis examined 201 quantitative studies that compared PBL as a treatment versus a lecture control, published between 1972 and 2007. The focus of this review was on comparing PBL treatments with lecture controls to determine if the subject matter (e.g. medicine, science, etc.), PBL method, problem type, or assessment type had an influence on the learning of students. This review attempted to fill some of the information gaps identified by previous authors in terms of what was happening in PBL. Walker and Leary noted that although medical education was the most common discipline listed in the studies that they observed, PBL appeared to be more influential when it was applied in other disciplines. While they note that this conclusion is based on a relatively small number of studies that were observed in disciplines outside of medicine, it does highlight the need for more work in these areas.

They used Barrows' (1986) PBL taxonomy to categorize the type of PBL where possible. Only five PBL studies mentioned the type of PBL used, again highlighting the need for more information.

Walker and Leary also used Jonassen's (2000) problem type categories, and found that the diagnosis solution problems of the type used in medicine were unsurprisingly the most commonly used. Based on a small sample of five studies that

specified that design or strategic performance problems, they cautiously concluded that these types of problems favoured PBL students (Walker & Leary, 2009). They also noted that there were several types of problems (e.g. decision-making problems) that were not represented in their sample of studies and many in which the problem could not be identified, so more information is needed.

Although in terms of assessment, they were in agreement with the 2005 work of Gijbels et al., that PBL students demonstrated moderately better results on assessments that measure practical applications and principles than lecture control students. Walker and Leary (2009) cautiously concluded that although PBL students generally performed as well as or better than lecture students, especially when the subject matter is outside of medicine, that some of their analyses are based on small numbers of studies, and that more information is needed.

Strobel and van Barneveld's 2009 qualitative meta-synthesis of meta-analyses – included eight qualitative and quantitative meta-analyses and systematic reviews authored from 1993 to 2005. Their analyses looked for key points and themes to examine how assessment impacts the conclusions about the effectiveness of PBL versus the traditional lecture classroom. They report that PBL is preferred by both students and faculty in measures of satisfaction, and that PBL is more effective than traditional lectures for applied learning and long term retention. Based on these conclusions and because studies have demonstrated the utility of PBL, they also suggest that the time is past for comparisons of traditional lecture versus PBL effectiveness, and should instead focus on how best to support student learning in the PBL environment (Strobel & van Barneveld, 2009).

### **PBL Method, Problem Characteristics and Supporting Problem Solving**

As noted by various authors comparisons between studies can be problematic because studies frequently do not describe which variant of PBL is being used (e.g. Barrows, 2002; Walker & Leary, 2009). To support the understanding of PBL we first examine the possible variants of the method of PBL that may be used based on Barrows' (1986) taxonomy; then review the characteristics of PBL problems, introduce Jonassen's (2000) typology of problems, and describe which types of problems are

most useful for PBL; and finally we define scaffolding and describe the use of hard and soft scaffolds.

### **Method of PBL.**

Although there have been many variations of PBL presented in the literature (see table below) since the inception of the method; there are four core elements to the original form of the PBL method (Barrows, 1986). First, the problems are ill-structured, authentic and presented as they would be under real circumstances. This facilitates discussion of multiple possible approaches and ideas about the problem. Second, the learning is self-directed. This means that students are responsible for determining what information or skills they need to address the problem; for locating, selecting and using their own resources from the available literature; and for sharing information with their peers. Third, the teacher's role is to facilitate the group interaction and provide a model for critical thinking and questioning skills rather than act as a source of information. Finally, the problems are chosen to reflect problems that are likely to be encountered in a professional situation in order to provide motivation and an organizing function for information (Barrows, 2002; Gijbels et al., 2005; McLinden et al., 2006; Savery, 2006).

These four basic elements were combined to address educational objectives including structuring and transferring knowledge to new situations; developing effective reasoning/problem-solving skills; developing self-directed learning skills; and increasing learner motivation (Barrows, 1986). The challenges of a traditional curriculum based on memorization, siloed course content, and limited attention to reasoning and problem-solving skills are not peculiar to medical education, so in recent years PBL has made the jump to teacher education, business, social work, science and other fields (Edens, 2000).

One of the problems inherent in trying to compare studies by different authors is the variety of approaches that can fall under the heading of PBL. Barrow's 1986 taxonomy of PBL methods provides a good overview of the major variations (Barrows, 1986).

Table 1 *Taxonomy of PBL Variants as Described by Barrows (1986)*

PBL variant	Characteristics of the Method
Lecture-based cases	Material is presented in class, then vignettes are presented to highlight its relevance. No self-directed research is required.
Case-based lectures	Case vignette or complete case history is presented which highlights the material to be covered in lecture. Case to be studied before lecture. No self-directed research is required.
Case method	A complete case is provided for examination and research prior to in-class discussion. Students may choose to do additional research, but it is not required. Case material is already synthesized and organized.
Modified case-based	Problem presentation does not include all relevant information and may be as a detailed vignette or a partial outline. In small groups, students brainstorm inquiry directions based on cues and restricted directions of inquiry.
Problem-based	Authentic problems presented to small groups. Free inquiry is required. Teachers or tutors may directly activate prior knowledge in exploration phase.
Closed-loop PBL or reiterative PBL	Extends the method described as the Problem-based variety. At the end students formally evaluate their approach to the problem to determine how they might have solved it more effectively.

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Based on (Barrows, 1986).

This variety in what constitutes PBL has been noted by various authors as a source of confusion because studies frequently compare PBL and non-PBL conditions without describing which variant of PBL is being used (Barrows, 2002; Walker & Leary, 2009). The variant of PBL used in specific studies is seldom explicitly named or described. In fact, Walker and Leary noted that only five of the 201 studies included in their analysis mentioned the type of PBL in use (Walker & Leary, 2009). The online PBL in the Ecotoxicology course that is the focus of this study is of the Problem-based variety as it requires free inquiry by the team with guidance from the instructor, and does not formally require the teams to critique their approach to the problem. However, interview data provided evidence of such reflection and critique informally occurring by students' own initiative (i.e., by those participants who were really wanting to perform well, or who were keen students).

### **Problem Characteristics.**

One of the strengths of PBL is how the problems can be used to show students the complexity of the interconnections between ideas and disciplines in a way that rewards creativity and the ability to understand a situation from a variety of perspectives. This is particularly true for fields like environmental science that by their interdisciplinary scope draw on a variety of tools, concepts and skills.

PBL is designed around the use of ill-structured problems that serve to present students with the kinds of challenges that they will face in professional practice. These are not the typical tidy "end of chapter" example problems from the textbook that serve to illustrate a specific point or procedure. These are authentic problems that provide the students with relevant "real world" kinds of contexts and experiences to illustrate the application of their learning as well as a focus and stimulus for learning (Barrows, 1996; Hmelo-Silver, 2004; Koschmann et al., 1994). In order to generate the deep learning required by PBL, these problems need to be complex enough to encourage discussion, preferably from multiple perspectives. Thus ill-structured problems are the focus for PBL because most real life or professional problems are of this type – and it is important to

note that there is no single “right” way to resolve the problem (Jonassen & Hung, 2008; Koschmann et al., 1994; Qin, Johnson, & Johnson, 1995).

Characteristics of ill-structured problems include that the problem is initially presented in an incomplete form (Barrows, 1996; Koschmann et al., 1994), that the problem evolves over time as more information is obtained, that decisions must be made based on incomplete information (e.g. identifying information gaps or the problem scope), and that uncertainty may persist about whether or not the correct decision has been made or interpretation has been used (Koschmann et al., 1994). Problems which include controversial or emotional elements can also increase student interest in the problem as well as provoking a greater quantity and depth of discussion (Dahlgren & Oberg, 2001; Edens, 2000). One of the other advantages to the use of authentic professional problems as the basis for learning is that it encourages students to integrate information from many different disciplines (Jonassen & Hung, 2008; Subramaniam, 2006), which increases the learner’s ability to understand how those disciplines fit together.

In 2000, Jonassen proposed a typology which describes the characteristics of eleven different types of problems and provides examples of the various types. The typology continuum ranges from well-structured problems such as logic problems and traditional story problems to ill-structured problems such as diagnosis-solution and dilemma problems. In some cases, the strategies and tools needed to solve lower level problems may be part of the approach needed to solve higher level, more complex problems (Jonassen, 2000). Not all problem types are equally suitable for PBL as some are too structured and require only the application of rote procedures, while others may be too ill-structured and fail to direct learning toward the desired goals (Jonassen & Hung, 2008). As PBL has its roots in medicine and medical education, and the majority of studies come from this field, it is not surprising that most of the literature in which the type of PBL problem is identified use diagnosis-solution problems (Walker & Leary, 2009). Jonassen and Hung (2008) used diagnosis-solution problems as the baseline to investigate what other types of problems may be the most amenable for use in PBL. The three problem types that they felt to be the most similar to diagnosis-solution problems in terms of balancing complexity and ill-structuredness were decision-making

problems, situated case/policy problems and design problems. Dilemma problems were felt to be too complex and ill-structured for use in PBL because of the high degree of effort needed just to define the problem and the conflicting possible perspectives (Jonassen, 2011; Jonassen & Hung, 2008). Dilemma problems could still be used for PBL, but their use may require instructors to provide scaffolding to limit the scope of the dilemma problem to an appropriate extent to meet the learning needs of their students.

### **Scaffolding.**

The design of the problems can also be used to scaffold novice students by moving them through a series of simple-to-complex tasks or sub-problems. By beginning with simpler problems, students can develop their background knowledge, motivation, group process and skills. As the problems become more difficult, the elements of the simple tasks can be revisited in the more complex problems, allowing further elaboration by a group that is now more confident in their ability to problem-solve (Brush & Saye, 2008; Edelson, Gordin, & Pea, 1999; Hmelo-Silver, 2004; Hmelo-Silver et al., 2007; Jonassen, 2011; Schmidt, Loyens, van Gog, & Paas, 2007).

Scaffolds are temporary supports that are provided to guide students through problems that they would not otherwise be able to complete (Schmidt, Rotgans & Yew, 2011). Scaffolds can be hard or soft. Hard scaffolds are designed in advance by the investigator, who is anticipating common student problems or errors; whereas soft or dynamic scaffolds are provided on an as-needed basis (Schmidt et al., 2011). Hard scaffolds can be faded out over time to encourage greater independence from students as they become more confident in their ability to solve the problems on their own (Schmidt et al., 2011).

In the problems designed for the PBL activity examined in this study, it was felt that the students would initially require scaffolds to help them. Therefore the first case included many hard scaffolds to provide guidance in determining the information gaps that would need to be filled. The number of hard scaffolds provided in the problems decreased from case one to case four. Soft scaffolds in the form of just-in-time teaching were provided for all cases in the PBL activity. Although the instructor felt that providing

scaffolding was important for students to be successful, the literature is inconclusive and more research is needed (Schmidt et al., 2011).

## **Distance Education**

This section will discuss some of the developments in distance education (DE) and how they have impacted the interactions between students, investigators and the content. This will be followed with a discussion of the adaptation of the PBL method to the online environment. Next, critical thinking as a process and a product will be discussed, and finally, the utility of online discussion groups to support student learning and interactions will be described.

### **What is distance education?**

Student success in Internet-based courses requires the same careful attention to instructional design, the same level of diligence on the part of the investigator and the same opportunity for meaningful communication that traditional in-class models require (Wegner, Holloway, & Garton, 1999, p. 105).

The tools of distance education have evolved over time from print-based materials delivered by post, through radio and television broadcasts, to today's generation of internet-delivered and supported, computer-mediated courses (Bernard et al., 2004). With each advance in technology, distance education has found itself with new media and greater possibilities for flexibility, interactivity and access (Bernard et al., 2004). Keegan distinguished distance education from other forms of education using the following features:

(a) the quasi-permanent separation of teacher and learner, (b) the influence of an educational organization in planning, preparation, and provision of student support, (c) the use of technical media, (d) the provision of two-way communication, and (e) the quasi-permanent absence of learning groups (Bernard et al., 2004, p. 380).

Because many distance education courses now include cohort-based or team-based online learning opportunities (e.g. the RRU programs described by this study) the quasi-permanent absence of learning groups may not necessarily apply, but overall this

definition of distance education is a good starting position. It emphasizes that the educational experience is occurring over a distance, and is using two-way communication to support the students and the learning community which develops. Although Keegan did not specify the use of computers or computer networks to provide the two-way contact between the students and investigators, Bernard notes that these specifications have now been made by other authors (Bernard et al., 2004).

The use of computers and the internet to provide two-way communication is critical to the learning experience. As noted by Moore, there are several types of interaction that are necessary for successful learning regardless of whether the instruction is face-to-face or at distance: interaction between the student and the content, interaction between the student and the instructor, and interaction between the students themselves (Moore, 1989). The student-content interaction results in a change in the student's understanding, perspective or thinking (Moore, 1989). This is the result of the learner taking the content and using it to construct their own knowledge, and occurs with both face-to-face and online delivered content. The student-instructor interaction provides an organizing function for learning by determining subject matter and order of presentation, as well as a resource for clarifying learning objectives, and again, in the investigator's experience, is an important part of teaching regardless of the format. The fact that interaction between students occurs is somewhat taken for granted in the face-to-face setting, but is attracting more attention in the realm of online (distance) learning (Moore, 1989).

The development of synchronous and asynchronous communication tools is allowing the students to establish supportive learning communities, also known as communities of inquiry (Garrison, Anderson & Archer, 2001; Meyer, 2003; Moore, 1989). These learning communities allow students to build and maintain the social connections that encourage students to discuss what they are learning and build knowledge together (Guilar & Loring, 2008; Garrison et al., 2001). These peer-to-peer interactions allow students to support each other in developing skills in both giving and receiving feedback as well as reduce anxiety about participating. The differences inherent in synchronous and asynchronous communication will be discussed below. Although it cannot be argued that the teaching medium (face-to-face or online) is a

neutral factor, it is apparent that “good” instruction will allow for all three types of interaction (between the learner and the content, between the learner and the investigator, and between the students), regardless of the medium being used (Moore, 1989).

### **DE versus face-to-face instruction comparisons.**

Bernard et al. (2004) conducted a meta-analysis of studies that compared DE and face-to-face classroom instruction using measures of achievement, attitude and student retention. Although all three measures examined in the meta-analysis (achievement, attitude and retention) showed an average effect size for distance education versus classroom instruction of near zero, the effect size results for individual studies varied widely with reported effect sizes showing 50% or more difference between the groups (some with distance education being better, some with classroom instruction being better) (Bernard et al., 2004). Additionally, given the possibility of bias in the published reports – that is, it being more likely for studies showing a positive effect of DE to be published by DE researchers, it is likely that the differences in effect between similarly supported DE and classroom instruction are small, and may show that DE is less effective overall. Given the heterogeneity in the types of activities included under the heading of distance education in this analysis, this is not a surprising result.

Interestingly, when the distance studies were separated into groups based on whether the communication used was synchronous or asynchronous, a difference between the two types was noted: synchronous communication was found to be less effective than classroom instruction, while asynchronous communication was found to be more effective than classroom instruction (Bernard et al., 2004). The authors concluded that the poorer performance for synchronous distance education may be due to “a tendency for synchronous DE investigators to engage in lecture-based, instructor-oriented strategies that may not translate well to mediated classrooms at a distance” (Bernard et al., 2004, p. 408). They also point out that synchronous tools do not allow students the same flexibility for anywhere/any time scheduling or the individual attention that is possible with asynchronous discussions (Bernard et al., 2004). In contrast, the increased flexibility and reflection time combined with better support for two-way interaction may produce “a better approximation of a learner-centered environment” (p.

409) for asynchronous communication tools and increase student motivation as a result (Bernard et al., 2004).

### **Distance education tools and PBL.**

As blended and distance education offerings become more common in the post-secondary sector, the question of how PBL can be adapted to the distance environment is being more closely considered (Barrows, 2002). This section will discuss DE tools that may support online PBL, and how the use of synchronous and asynchronous communication would impact online PBL. One of the first challenges for PBL as a method for distance education is whether or not DE tools have the capability to successfully handle the various aspects of PBL.

To address this question, McLinden separated the activities that are part of PBL into three broad categories: information-related, communication and collaboration-related, and assessment-related (McLinden et al., 2006). McLinden suggested that information-related activities were those that are related to individual research skills – for example, the location, selection, analysis and synthesis of information (McLinden et al., 2006). These skills can clearly be used by distance students through access to various computer databases, search engines, citation managers and other online resources (Edelson et al., 1999; Ellis, Goodyear, Brilliant, & Prosser, 2007; McLinden et al., 2006). Due to the prevalence of internet resources, in many cases these online resources are the same ones being used by students that are engaged in face-to-face PBL. Communication and collaboration-related activities involve challenging, questioning and co-constructing knowledge between peers and tutors (McLinden et al., 2006). There are both synchronous and asynchronous options for distance tools that can mediate these activities, which will be discussed in more depth below. Assessment-related activities can include the production of artifacts that demonstrate the application of the learning, as well as self and peer assessment activities (McLinden et al., 2006). The use of collaborative writing tools such as Google Docs, wikis or the simple use of the “track changes” feature in a word processing document can allow students to generate collaborative products. Additionally, online surveys can be used for both self and peer assessments. In the RRU BSc programs online surveys for self and team

assessments were used with both distance and face-to-face students, although the research agreement precluded their inclusion in the data for this study.

Communication and collaboration-related activities and the electronic tools to support them are a key aspect of online PBL (Koschmann et al., 1994; McLinden et al., 2006). In face-to-face PBL, the group meetings are the location in which students brainstorm, agree on learning issues, present and critique research, learn questioning and feedback skills, etc. In an online environment, the facilitator needs to promote communication and critical thinking, model questioning and feedback as well as keep the group on task (Dennis, 2003; Garrison et al., 2001). This feedback role is critical to the group success because there is the potential for misconceptions in the group's learning to remain uncorrected if the facilitator does not provide adequate feedback or probing to ensure complete understanding (Orrill, 2002). Online communication environments can take the form of either synchronous discussion (e.g. chat) or asynchronous discussion (e.g. threaded discussions). This is an important distinction that has implications for the communication that takes place between the students (Tallent-Runnels et al., 2006). Wertsch notes that

it is possible to recognize a general distinction between the giveandtake of intense, rapid-fire, face-to-face dialogue, where utterances are often fragmentary and interrupted, on the one hand, and a sequence of turns, each of which involves an extended, maximally explicit, fully developed, and uninterrupted utterance, on the other (Wertsch, 2002, p. 108).

This is an important observation because synchronous and asynchronous discussions are fundamentally different and sit on opposite ends of a communication continuum. Synchronous communication, where all members of the group are online simultaneously, flows like a face-to-face dialogue, with speakers interrupting each other, and the possibility of missing the opportunity to add your point to the discussion if you don't contribute it before the conversation moves on in a new direction (or the possibility of chaos as you add your thoughts on a topic that has passed). Asynchronous discussion, such as threaded discussions, expands the time for a conversation, allowing each speaker to hold the floor as long as they wish, and the ability to reflect on their own and other's ideas, and to contribute to a thread when they are ready (the

conversation might move on but can easily be re-visited) (Meyer, 2003; Wertsch, 2002). Wertsch concurs and points out that

the use of newer asynchronous communication systems may be introducing a larger element of change into PBL, and its consequences for cognition, identity, and collaboration, than we normally recognize (Wertsch, 2002, p. 108).

The question then becomes is this change to asynchronicity for PBL good, bad or simply different? The group process and the critical thinking that go along with it are key aspects of PBL. Asynchronous communication introduces greater flexibility for team participation and the element of reflection time into the process (Tiene, 2000). This time may allow students to demonstrate critical thinking by linking ideas, supporting arguments with evidence and debating multiple perspectives (Meyer, 2003; Tiene, 2000) in a way that is not possible when the conversation moves as rapidly as it does in both face-to-face and synchronous online chat situations. Similar to the observations of other authors, the investigator's experience indicated that using online asynchronous communication to support PBL in a face-to-face class allows for a deeper and more sustained interaction with the course material than was possible in a face-to-face classroom (Li, 2006; Tiene, 2000). From this perspective, this "slower" form of PBL appears to be advantageous. However, like Kim et al. (2006), the investigator also noticed that asynchronous PBL discussions may also be a disadvantage if a decision needs to be made quickly (e.g. it is necessary to decide this before the next step can be undertaken). For example, the group may have difficulty in reaching a rapid consensus, especially for teams that are new to working with each other (Kim et al., 2006).

Synchronous online communication tools provide a similar experience to face-to-face discussions and because of its faster exchange of ideas may be better suited to rapid decision making than asynchronous discussions. Dennis' study comparing synchronous discussion PBL to face-to-face PBL of physical therapy students found no significant difference in learning outcomes between the two groups but noted that the distance students reported spending more time-on-task (2003). There may be several reasons behind this observation. It is possible that the distance students may have been reading more deeply or broadly to support their learning, which would align with the

inferences of Dennis (2003). Dennis suggested that this increased time-on-task may have been due to the students compensating with more independent study for online group sessions that were less productive (Dennis, 2003), something that has also been reported in studies of face-to-face PBL tutorials (van Berkel, Henk J. M. & Schmidt, 2000). Another contributing factor to the greater time-on-task reported by the distance students may be that it takes more time to compose, type and refine their thoughts than it does to speak. This extra attention to their posts may make them more thoughtful and effective as communication tools, even in the absence of the body language that contributes to face-to-face communications. Dennis also noted that regardless of whether PBL was conducted online with synchronous discussion or face-to-face, groups that generated and tackled the most learning issues during their discussions had the highest achievement (Dennis, 2003).

The investigator also liked the use of the online discussions for face-to-face classes because it provided a greater opportunity for reflection and as noted by Li:

The flexible nature of online discussion allows sustained dialogue without taking too much time and space from limited face-to-face interaction. On the other hand, ideas and concerns generated in online dialogues, when appropriate, can be broached in face-to-face classes (Li, 2006, p. 214).

This ability to bring learning issues from the online discussion into the face-to-face classroom is a useful method of providing scaffolding in the form of just-in-time teaching to support to student learning. This may be particularly important for the blended students in this study who tend to be younger than the distance students and may have less work experience to draw upon.

The RRU BSc programs (both distance and blended) used asynchronous threaded discussions for their online PBL in the Ecotoxicology course. The instructor felt that asynchronicity provided two great advantages: flexibility and reflection time. Flexibility in time and space was important because teams include members distributed across Canada (distance students), or with different work schedules (distance and blended students). Having the time to reflect on their learning was considered to be a key contributor to the critical thinking that the investigator wanted to see in their discussions and subsequent deliverables based on those discussions.

The use of online PBL is in clear alignment with the Royal Roads LTM, which includes technology-enhanced learning is one of the key features (Royal Roads University, 2013b). Additionally, given the increasing emphasis on online education for professional development and the use of geographically distributed teams for large scale projects, online PBL may allow students to develop a valuable employment skill - the ability to collaborate with others in an online environment.

### **Critical thinking in the online environment.**

While instructors hope to create learning situations where students can make deep and meaningful connections between themselves and what they are learning, students may approach their learning in ways that do not always meet these instructional goals. This section examines these approaches and how they connect to the idea of critical thinking as a process and a product.

The approaches that students take to their learning can be categorized into surface, achieving and deep approaches. Surface approaches are used by students who just want to survive their academic experience and tend to be focused on reproduction strategies (memorize and dump onto the exam) or applying a known series of steps to resolve a situation (Ellis et al., 2007). These students can often find information or quote definitions but are unable to apply or link the new knowledge to previously learned information. Achieving approaches are used by students whose priority is gaining the highest marks possible (Ellis et al., 2007). These students employ many of the same strategies as the surface students and frequently ask "is this going to be on the exam". They may use some deep strategies but due to their focus on imminent short term goals, their long-term retention of knowledge tends to be poor (Ellis et al., 2007; Kanuka, 2005). Both these groups are focused on what Orr would categorize as approaches that feed their cleverness rather than their intelligence (Orr, 1994b). Deep approaches are used by students who want to really understand the concepts (Ellis et al., 2007). They read widely, engage critically with the material, make linkages with previous knowledge and experience, and actively construct knowledge (Ellis et al., 2007; Kanuka, 2005). It should be noted that most students are able to use any of the various approaches, and which one they use may vary from situation to

situation (Kanuka, 2005). Since deep approaches are those that involve critical thinking, in an ideal world, it would be good to see all students using deep approaches. Trying to engage students in authentic, relevant and motivating learning activities such that they are intrinsically motivated, rather than extrinsically motivated (Goodell & Yusko, 2005; Herrington, Reeves, & Oliver, 2006) may encourage students towards the use of deep approaches.

Increasing the critical or higher order thinking skills (deep approaches) of students is considered to be a key objective for education. This suggests that we should be able to define what skills might be included in critical thinking as well as design assessments that would measure the acquisition of these skills. Garrison suggests that critical thinking skills include attributes such as creativity, problem-solving, intuition, and insight (Garrison et al., 2001). As Garrison points out:

Critical thinking is both a process and an outcome. As an outcome, it is best understood from an individual perspective – that is, the acquisition of deep and meaningful understanding as well as content-specific critical inquiry abilities, skills and dispositions....As a product [outcome], critical thinking is, perhaps, best judged through individual educational assignments. The difficulty of assessing critical thinking as a product is that it is a complex and (only indirectly) accessible cognitive process (Garrison et al., 2001, p.2).

This is the difficulty in evaluating critical thinking – are we measuring the outcome (which is easier to observe from the assignments or artifacts which are required as deliverables from students) or are we measuring the process (a more difficult proposition)?

As Garrison points out we can only use writing and speaking as surrogates for thinking – in effect, we are only able to see what students choose to reveal with respect to their thinking process (Garrison et al., 2001). While the compiled posts of an online discussion group have the advantage for research analysis of not requiring the consideration of nonverbal forms of communication that may be occurring, it is important to remember that individual and group exploration of ideas is happening that cannot be observed in the written text (Garrison et al., 2001). Garrison cautions that:

There may be a variety of technical, access, or deeper social, psychological, and educational inhibitors to participation in the conference, which means that the transcript of the conference is a significantly less-than-complete record of the learning that has taken place within the community of inquiry (Garrison et al., 2001, p. 7).

This limitation to the use of discussion transcripts should be borne in mind when using participation in online discussions as an aspect of assessment of group process or critical thinking. Accessing these other aspects of the group process or critical thinking may require the use of self- and team-assessments or the use of learning journals (Ward & Lee, 2002). In this study, interviews with selected participants were used to explore other factors which influence what students choose to post.

### **The utility of online discussion forums.**

Online discussion forums are the primary data source for this study. This subsection examines how online discussions are useful for teaching critical thinking. It will also describe the interaction between critical thinking and the development of the learning community within the team as the online discussions continue.

Online discussions are considered to be a good way to teach critical thinking skills because they have the advantages of traditional writing assignments, and of presenting multiple possible viewpoints (Greenlaw & DeLoach, 2003). Writing assignments give students the opportunity to clarify their ideas, demonstrate linkages and develop supported arguments. Individuals often do not know what they know until they are encouraged to focus and write their thoughts down, so writing is a good way to see what students are thinking about (Greenlaw & DeLoach, 2003). The online discussion format evens the playfield of presented ideas compared to the face-to-face classroom. Because ideas in the discussion forum can be contributed by both the instructor and peers, the students need to compare and evaluate the diversity of ideas that are presented (Greenlaw & DeLoach, 2003).

In agreement with the work of other authors (Kanuka, 2005; Ronteltap & Eurelings, 2002), the investigator's experience suggested that it is often helpful to mandate that contributions to the online discussion be in the learner's own words with

appropriate citations. This guideline helps to avoid simple “cutting and pasting” from source material and requires students to process the information more completely, resulting in a higher level of cognitive activity (Kanuka, 2005; Ronteltap & Eurelings, 2002). In addition, the provision of citations allows the other students as well as the instructor to evaluate the reliability of the various information sources (Greenlaw & DeLoach, 2003). The ability to evaluate source materials is an important critical thinking skill for the student’s future in the workplace.

Rogers found that as students became more accustomed to the online discussion format, they became increasingly sophisticated in their questioning skills, their openness, their confidence in assembling ideas, their readiness to respond critically to the ‘moderator’ as well as peer-group members and to revisit previously held conceptions or misunderstandings (Rogers, 2004, p. 240).

This suggests that, similar to face-to-face groups, as the online group becomes established the students become comfortable with the group process and find the online forums to offer “an extended and safe communication environment to argue and disagree without involving excessive conflict” (Li, 2006, p. 210). These more experienced students become more engaged in the discussions and use conversational approaches to their postings, which are more frequent and detailed than is observed from novice groups (Bjorck, 2002). In addition, these students are more likely to comment on each other’s comments. This behaviour builds community and encourages reciprocity and engagement in the group process (Bjorck, 2002; Garrison et al., 2001).

Groups may initially need scaffolding in skills such as reflection, feedback and questioning but they will move to independence in these areas as they become more experienced (Kanuka, 2005; Yang & Chou, 2008). Jonassen (2011) notes that:

Because PBL represents a significant shift in learning for most students, they require support in adapting their learning methods. We cannot assume that learners are naturally skilled in problem-solving, especially complex and ill-structured problems such as those required in most PBL programs (p. 96).

Although simple participation in an online discussion will not necessarily improve critical thinking skills (Kanuka, 2005; Yang & Chou, 2008), students in a graduate education course found the online discussions useful because they “felt they learned to think more critically and that they could not get through the course by working hard only at exam times” (Meyer, 2003, p. 58). The review by Tallent-Runnels et al. indicates that students who are actively involved in the online discussions earned higher grades than students who were not (2006). Active involvement certainly implies that the students are doing more than just posting information gleaned from source material as that would be insufficient to sustain an active dialogue. Such a dialogue would require reflection and response to the postings of other group members and would aid both in the construction of group knowledge and in the formation of a mutually supportive community of inquiry (An & Frick, 2006; Edelstein & Edwards, 2002).

Online discussions are a useful addition to both distance and blended classes. Online discussion forums provide a useful means for students to develop critical thinking skills as they write about what they are learning. By encouraging students to write posts in their own words, they develop skills in writing, linking ideas and critically evaluating source materials. The instructor can provide scaffolding and modelling of appropriate behaviour as students develop feedback, questioning and problem solving skills.

### **Community of Inquiry Model**

Moore (1989) felt that “good” instruction would allow for interaction to occur between the learner and the content, between the learner and the investigator, and between the learners, regardless of the medium being used (Moore, 1989). The community of inquiry (CofI) model provides a way to describe how these interactions together provide a quality online learning experience (Garrison et al., 2001). Garrison and Anderson (2003) describe an online education experience as being made up of three intersecting parts – cognitive presence, teaching presence and social presence (see Figure 1). These parts roughly correspond to the interactions described by Moore (1989). The following sections will describe the behavioural indicators for each of the presences. The cognitive presence indicators are discussed in the most detail because

several of the research questions are related to critical thinking. In this study, the cognitive presence behavioural indicators are used to code instances of critical thinking. The CofI cognitive and social presence indicators will be used in the content analysis of this study. The teaching presence indicators will be referenced during the discussion of the results of the study, but were not used as a set of codes in the content analysis. Although the three presences will be described as if they were separate entities, it should be noted that they overlap and influence one another (see Figure 1).

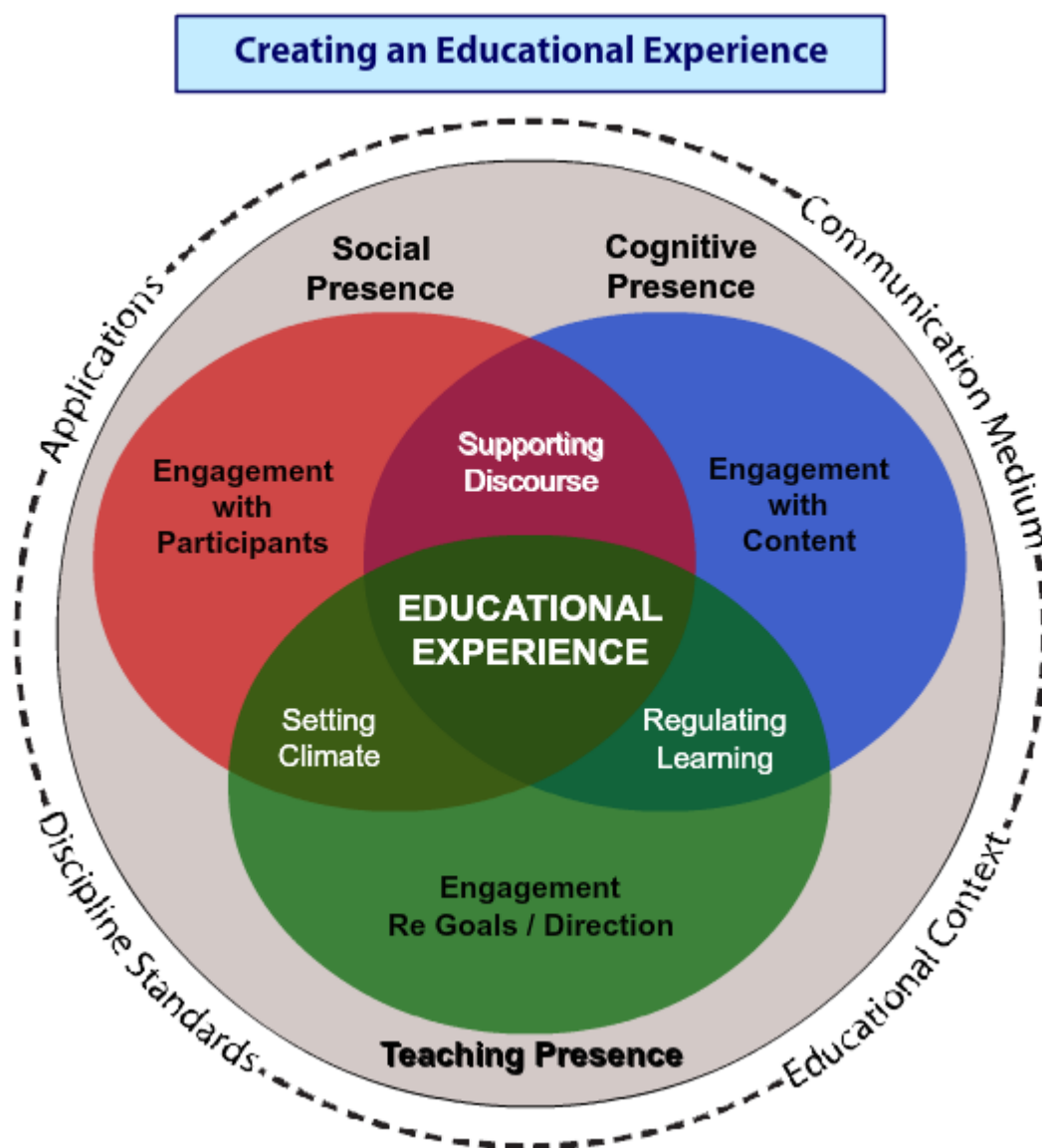


Figure 1. Community of Inquiry model. From Garrison, D.R., Cleveland-Innes, M., & Vaughan, N.D. (2016). Community of inquiry framework. Available online at:

<https://coi.athabascau.ca/wp-content/uploads/2014/07/COI-ANIM.swf> Reprinted with permission.

### **Cofl cognitive indicators**

Garrison's group developed the practical inquiry model to describe the process of critical inquiry (critical thinking). The practical inquiry model as described by Garrison expands upon the Cofl cognitive presence indicators and operationalizes them with four phases for critical thinking: triggering, exploration, integration, and resolution. In the triggering stage, a problem is recognized. Depending on the educational framework, the problem may be ill-structured or defined, and is posed by the investigator or by another learner. In the exploration stage, the students first characterize the nature of the problem and then explore relevant information. In the integration stage, meaning is constructed, and ideas are tested. Teaching presence is important in this phase to correct misconceptions and move the discussion toward the final resolution phase (Anderson, Rourke, Garrison and Archer, 2001). In the resolution phase, a solution may be implemented and examined or tested through further discussion. It should be noted that a resolution may lead to additional triggering events for complex problems (Garrison et al., 2001). Interestingly, these phases are also useful in describing the way in which PBL is approached – a triggering question or situation is posed; exploration takes place both within the group to establish learning issues and activate prior knowledge, and in a self-directed research phase; integration occurs when groups report back on their research and provide each other with feedback; and a resolution phase occurs in which the group decides whether it has solved the problem and addressed its learning issues or it needs to generate more learning issues (leading to another triggering event). It is necessary to design discussion questions in such a way as to encourage students to reach the integration/resolution phases that are considered to be indicative of higher order thinking skills (Garrison et al., 2001).

It is important to note that discussions (both online and face-to-face) can stall at the exploration phase if students are not encouraged to move towards integration and resolution (Anderson et al., 2001; Garrison et al., 2001; Kanuka, 2005; Meyer, 2003). This requires the facilitator to direct questions to group members to push them to justify

their thinking, and engage in self-reflection and feedback about the material generated in the exploration phase (Hmelo-Silver, 2004; Hmelo-Silver & Barrows, 2006). Anderson et al. (2001) suggest that this observation is a reflection of the requirement for teaching presence within the online discussion to encourage higher levels of critical thinking. An online environment can be useful in this process because integration and resolution steps require that the individuals involved have time to engage in reflection, which can be facilitated by an asynchronous environment where an individual can respond when they are ready (Meyer, 2003). This is particularly important when PBL is being used – the discussion and debate that allow students to receive feedback and reflect on their learning are necessary to ensure deep learning is happening, and must be taught through active modeling by the facilitator or using alternative activities such as learning journals (Dunlap, 2006; Hmelo-Silver, 2004), and supported through active teaching presence (Anderson et al., 2001).

### **Cofteaching indicators.**

Teaching presence is defined as “the design, facilitation, and direction of cognitive and social processes for the purpose of realizing personally meaningful and educationally worthwhile learning outcomes” (Garrison & Anderson, 2003 p. 29). Teaching presence has three indicators: design and organization; facilitating discourse; and direct instruction. The design and organization indicator includes behaviours such as the design and layout of the assignments, readings and other resources/activities of the course. These include all the planning activities that are done before and during the course, including the design of any hard scaffolds that the investigator is planning to use. The facilitating discourse indicator includes behaviours such as encouraging student interaction and discussion. The final indicator, direct instruction, includes behaviours such as providing information/advice and clarifying ideas (Anderson et al., 2001; Vaughan, Cleveland-Innes & Garrison, 2013). Direct instruction is an important soft scaffold in online discussion forums. The teaching presence indicators can provide evidence of the presence of important supports to student learning (Garrison et al. 2001; Guilar and Loring, 2008; Anderson et al., 2001, Vaughan et al., 2013). The instructor’s discussion contributions in the form of direct just-in-time instruction (teaching

presence) can be used to correct misconceptions in the discussion, as well as modelling questioning that facilitates the discussion moving toward integration of ideas and eventually resolution (Anderson et al., 2001; Vaughan et al., 2013) – this is a critical contribution to collaborative constructive learning environments such as PBL, and is one of the reasons that completely unguided PBL is often an unsuccessful educational strategy (Kirschner et al., 2006). The importance of the contribution of teaching presence in this study will be discussed further in the interpretation of the organization indicator in chapter five and six.

### **Cofl social indicators.**

Social presence is “the ability of participants in a community of inquiry to project themselves socially and emotionally, as ‘real’ people, through the medium of communication being used” (Garrison & Anderson, 2003, p. 28). The three indicators for social presence are affective communication, open communication and cohesion. Affective communication behaviours include such things as expressing emotions, using humor, or telling the team something about yourself or your feelings (self-disclosure). Open communication behaviours include referring to or quoting from someone else’s message; complimenting someone’s post; agreeing with other’s posts; or replying to other’s posts. Cohesive behaviours include referring to others by name, using inclusive pronouns, and using salutations to start a message (Garrison & Anderson, 2003, p. 51).

### **Cofl and content analysis.**

Content analysis is a methodological approach to analyzing the transcripts of asynchronous online discussions in order to make inferences about the underlying learning behaviour and knowledge construction that may be occurring (De Wever, Schellens, Valcke & Van Keer, 2006; Garrison, Cleveland-Innes, Koole & Kappelman 2006; Heckman & Annabi, 2005). There are many available content analysis frameworks in the literature – in fact a review by De Wever et al. (2006) provided an overview of fifteen models. The models differ with respect to their theoretical basis, focus, and methods including reporting of inter-rater reliability. The Cofl model put forward by Garrison et al. (2001) was selected because it incorporated a straightforward coding scheme with validated indicators that can be used to examine higher order thinking

skills, and it was developed to examine asynchronous online discussions, which were the focus of this study. The structure of this model has been confirmed by factor analysis in two separate studies (Arbaugh, 2007; Garrison, Cleveland-Innes, & Fung, 2004). This model has been used by researchers outside of the Garrison group, thus allowing comparisons to be made to other research studies (e.g. Heckman & Annabi, 2005; Meyer, 2003). Additionally, the instructional designers at Royal Roads University have used the community of inquiry model as a design framework and as a result, it aligns well with the RRU LTM (Royal Roads University, 2013b). This study provides an opportunity to examine online asynchronous PBL in the RRU instructional context.

### **Concluding remarks**

The field of PBL has evolved from a good idea into an educational approach with theoretical underpinnings in just over fifty years. The last twenty years have seen a major shift in PBL research with the recognition that PBL cannot be evaluated as single variable, but rather it encompasses many variables including: problem solving, team work, research and communications. This recognition leads to investigations of more subtle variables that may contribute to PBL's effects, as well as the integration of technology into the PBL approach.

This chapter reviewed the literature on PBL, distance education, adapting PBL to the online asynchronous environment, and critical thinking in discussion posts. The three presences that make up the community of inquiry (CofI) model and their behavioural indicators that will be used in the study were discussed. The cognitive and social presence indicators will be used for coding purposes in this study, while the teaching presence indicators will be used when discussing some aspects of the results. This study represents an attempt to focus on critical thinking exhibited by both distance and blended program students in online asynchronous PBL discussions and the various influences that might impact it.

## **Chapter 3 Methods**

The impetus for this study was the investigator's observation that the teams from the distance and blended cohorts appeared to approach the PBL problems and use the online discussion forums differently. This mixed methods study compares the approaches and online behaviour of distance and blended students when engaged in online PBL activities. More specifically, the apparent similarities and differences in students' critical thinking are examined using CofI cognitive presence indicators to categorize the written contributions of distance and blended undergraduate environmental science students as they completed four linked PBL cases online. Some of the variables that impact the demonstration of critical thinking when students are engaged in online PBL using asynchronous discussion forums were also examined.

Data was captured from four cohorts of BSc distance students (2004, 2006, 2008 and 2010) and four cohorts of BSc blended students (2004-2005, 2006-2007, 2009-2010 and 2010-2011) enrolled in programs at RRU. Data for this study includes the compiled online discussion posts of the students enrolled in each cohort, as well as the transcripts of interviews with two members of the 2010 distance and two members of the 2010 blended cohort. Although it was hoped that more interview data would be available, the interviews provided some useful insights into the team process for online PBL case problems.

This chapter begins with a discussion of the two data sources (archived online PBL discussion forums and interviews) and the ethical approval permissions required for the use of each. This is followed by a description of the procedures for the quantitative and qualitative analyses.

### **Ethical Approval and Participant Permissions**

This study received ethical approval from both the University of Victoria and Royal Roads University. The secondary use of archival data in this study and the investigator's status as a RRU faculty member also necessitated a research agreement between Royal Roads University and the investigator. The data is from two sources: archived discussion forums and direct interviews. The necessary permissions for use of the two data sources were different and will be described in the sections below.

### **Archived discussion forums.**

This study focusses on four cohorts of BSc distance students (2004, 2006, 2008 and 2010) and four cohorts of BSc blended students (2004-2005, 2006-2007, 2009-2010 and 2010-2011). Students were assigned to the various cohorts based on their registration in one of two BSc programs, and as either distance or blended students in a particular year. Students take the Ecotoxicology course in the form mandated by their registration.

Given that students enter both programs from across Canada and may then move for personal or employment reasons following graduation, contacting all potential participants from these cohorts was not possible. Full consent was not required as these data were examined under an approved exemption 3.7 of the Tricouncil Policy Statement version 2 (Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, 2010). This is a minimal risk study, and does not involve therapeutic, diagnostic or clinical interventions.

The archived online discussion forums for all the distance and blended cohorts were examined and reported on as anonymous aggregated data to protect the privacy of individuals. The quantitative results are reported as cohort means only. Pseudo-comments and pseudo-examples are used in this report to illustrate typical responses or examples from the content analysis where needed.

### **Interviews.**

The purpose of the interviews was to help to validate the investigator's interpretations of the qualitative analysis of the thread diagrams and content analysis. Although the investigator has continued to teach the Ecotoxicology course to the present time, the interviewees were recruited by open invitation to all previous students from the BSc Environmental Management program 2010 cohort (distance) and the Environmental Science program 2010-2011 cohort (blended). Interview recruitment focused on these two cohorts because of interview timing, program completion and relative accessibility. First, the interviews were conducted in the late fall of 2012, and these cohorts had both recently graduated and used the same PBL problems for the PBL activity. As the next distance class (the 2012 cohort) would not have graduated until

fall of 2014, the 2010 classes were selected as the cut-off point for inclusion in the analysis in this study. Secondly, the prior teacher-student relationship that existed between these students and the investigator was finished, and their retrospective observations were likely to be less distorted because they were the most recent graduates of their respective programs. Pragmatically it was also expected that contact information for the 2010 distance and blended cohorts would be more up-to-date. Potential interviewees were contacted within two years of the completion of their program of studies at Royal Roads University. Since a power-over relationship with the potential interviewees was no longer in place, they were under no obligation to participate in the study if they did not wish to.

Full, informed consent was sought for interview participants as noted in the Tricouncil Policy Statement version 2 (Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, 2010). Contact was initiated via an email invitation that explained the study and invited their participation. The consent form was included as an attachment. Please see Appendix A for a copy of the approved invitation and consent form, interview questions and ethics certificates.

## **Procedure**

Figure 2 is a flow chart of the procedures used in this study. Each of the steps will be described in the sections below, starting with the steps that applied to the online discussion transcripts including: data preparation, and the NVivo coding of the posts using the Cofl cognitive indicators. The procedure then splits into the quantitative component, including ANOVA and independent *t*-test analyses; and the qualitative component, including the thread maps, content analysis and interviews. The thread maps and content analysis guided the generation of the semi-structured interview questions that were in turn used to validate, explain, and elaborate on the thread map and content analysis results.

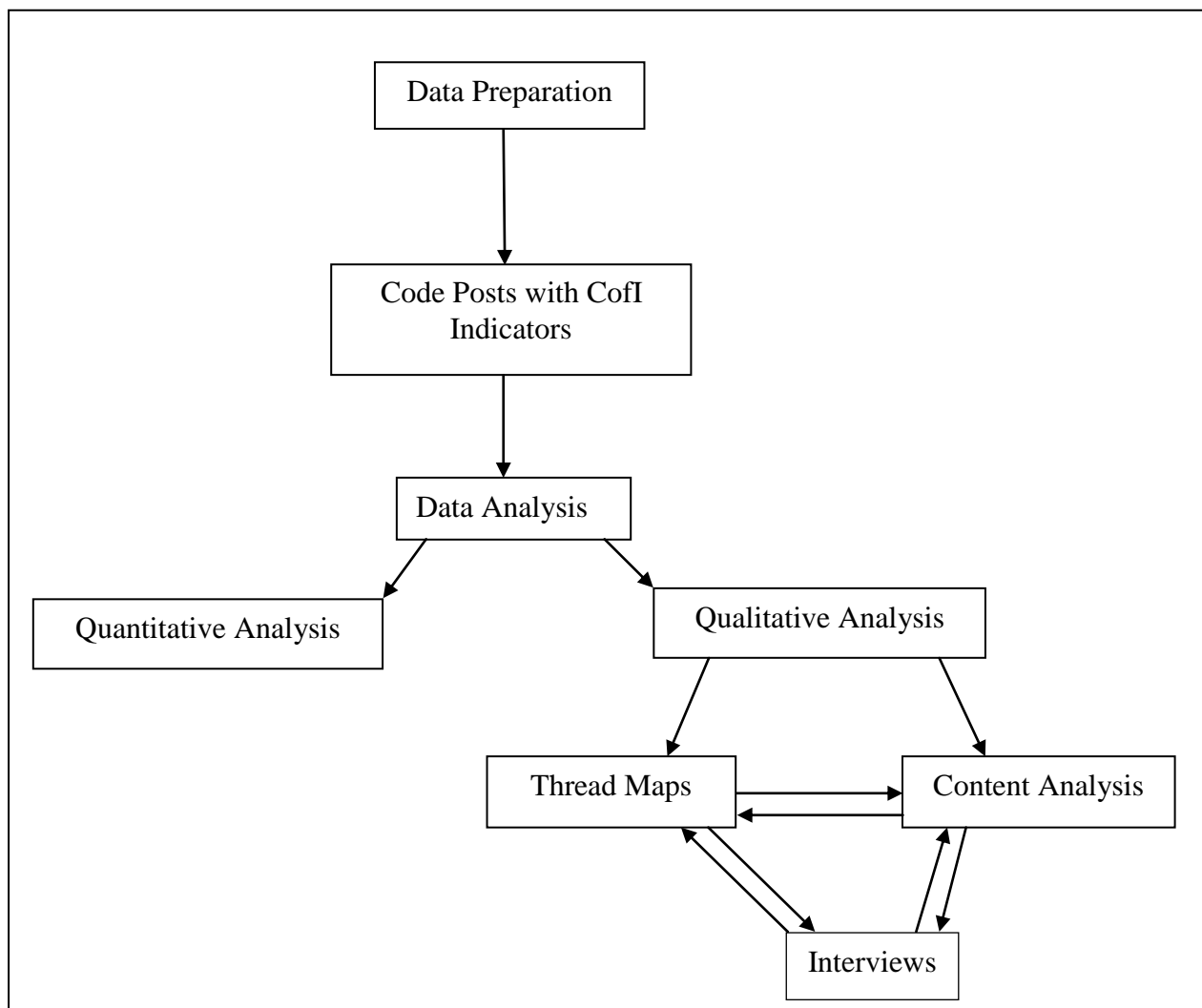


Figure 2. Procedure Flow Chart

**Data preparation (all cohorts).**

As noted in the description of the instructional design of the Ecotoxicology course, all distance and blended cohorts participated in the online PBL activity using asynchronous discussion forums. These discussion forums were located on the course website where participants could post, read, and respond to each other's messages asynchronously. The discussion forums for all the cohorts reside in the archived Moodle-based course sites for ENSC 407 Ecotoxicology on the RRU server system. The online PBL task for all cohorts consisted of four parts, referred to as “cases one to four”. The course Moodle site included a private discussion area for each team in the cohort for each case. The instructor could read all posts made to the discussion forums in the course, including those in the private team areas, and all posts have their authorship identified. It should also be noted that students could only edit or remove their posts within 30 minutes of submitting their post to the discussion forum. During this time, the post is not visible to anyone except the author of the post. After 30 minutes, posts become a permanent part of the discussion unless their removal is requested by the instructor from the instructional design staff. This is not usually done unless the post violates university policy.

The archived discussion forums for each team and case were downloaded as compiled transcripts (HTML files) from the archived Moodle course sites. Any files that students had attached to their discussion posts (e.g., Excel, Word, PDF, Paint or Powerpoint files) had to be separately downloaded as they were not included in the compiled transcripts. Because the names of any attached files were noted in the compiled transcripts, the attachments could be matched up to the appropriate posts.

PrimoPDF was used to convert the compiled transcript HTML files to PDF. The PDF files were needed in order to maintain the appearance and formatting of the discussion posts when the compiled source material was imported into QSR NVivo10 for coding and analysis. Maintenance of the appearance and formatting of the posts was important as it allowed the relationships between individual posts to be readily recognized by the borders surrounding each post. The attachments were not imported into NVivo10 because there was not a straightforward way to import attached files and keep them connected to the correct discussion post. The attachments were

examined for evidence of critical thinking as well as the source of any citations that were included. Any information that was captured from the attachments was included in the coding of the discussion post they were associated with.

### **Data coding using Cofl cognitive indicators.**

The discussion posts that occurred during the PBL activity were coded in NVivo10 using the cognitive presence indicators from the Cofl model (triggering, exploration, integration, resolution or social/other) developed by Garrison et al. (2001) to describe critical thinking and inquiry based on the content analysis of asynchronous online discussion forums. Each post in each discussion forum was categorized as triggering, exploration, integration, resolution or social/other post. Triggering posts are those in which students ask questions that take the discussion in new directions, propose new tangents to the discussion, or present background information leading into a question. Exploration posts are those posts that include contradictions, personal narratives, opinions, and brainstorming. Integration posts build on ideas, substantiate points, provide evidence, integrate ideas from several different sources and discuss or refer to other members' posts. Resolution posts are those posts in which students test and defend possible solutions or discuss applications to real world situations. Note that the resolution category was adjusted during the coding process and this adjustment will be discussed in chapter four and five. Other/social posts are messages that may be community building but not related to the discussion (Garrison et al., 2001; Meyer, 2003).

A further category, organization, was added after the initial pass through of the data to help classify the large number of "other" posts in which student moderators copied the hard scaffolds from the problem into posts that served an organizing function in the discussion. The addition of this category to the cognitive presence indicators will be discussed in chapter four and five.

The categories for the Cofl cognitive presence indicators were meant to be mutually exclusive, so each post was coded to a single category (Garrison et al., 2001). When a post seemed to potentially fit into more than one category, the approach used by Garrison et al. (2001, p. 17) was adopted, i.e., the post was coded to the earliest category present if it was unclear which category was present, and coded up to the

highest level category (in terms of critical thinking), if the post contained clear indicators of several categories. For example, if a post contained possible indicators of exploration and integration, but it was unclear which category was the best fit, the post would be coded as an exploration post. However, if there were clear indications of both exploration and integration behaviour in the post, then it would be coded as an integration post because the student appeared to be moving towards higher level thinking. The investigator was responsible for all coding in this self-study, and therefore no inter-rater reliability data is available. However, similar to the approach taken by Rourke et al. (2001), the posts for the distance 2004 and blended 2004 cohorts were re-coded on two separate occasions after the initial coding was done to check the coding consistency over time.

### **Data analysis.**

Following the data preparation and Cofl-based coding described in the previous sections, the discussion forum data was subjected to both quantitative and qualitative analysis by the investigator. The methods used for the data analysis are described here, while the details of the analysis and the consistency of the coding will be discussed in chapter four.

### ***Quantitative component.***

A quantitative approach was used to help address the following research questions (see Figure 2):

2. In what ways do the levels of critical thinking observed in students from distance and blended courses differ in similar online PBL situations? What elements influence this?
3. How do the observed levels of critical thinking change as students from distance and blended cohorts progress through a sequence of four PBL cases in the Ecotoxicology course?

Garrison et al. (2001) and Meyer (2003) agree that the categories of exploration, integration and resolution represent higher-order thinking skills (critical thinking) because such posts involve the students in activities such as brainstorming, creating solutions, defending ideas, and constructing knowledge. In this study, the level of critical

thinking for each student's discussion posts was quantified based on coding of the discussion posts to the exploratory, integration, and resolution categories of the Cofl model. Students varied both with respect to the number of posts in each category as well as the total number of posts. The number of posts categorized as exploration, integration and resolution were totaled for each student across all four PBL cases, and this total was used as their PBL critical thinking (PBL-CT) score. The PBL-CT score was used as the operational measure of critical thinking in this study. The critical thinking learning outcome was also assessed on the scenario portion of the final exam. This part of the final exam was designed to be similar to the PBL problems used in the course. A student's score on the scenario portion of the final exam is their FE-PBL score. The FE-PBL score and the PBL-CT score were examined using correlational analysis, as well as being used independently to examine the relative achievement of distance and blended cohorts.

Frequency counts of each type of post were done using NVivo queries, and compared to literature values (e.g. Garrison et al., 2001; Meyer, 2003). The number of posts categorized as exploration, integration, or resolution was calculated for each student within a team case discussion forum, and this total was used as their PBL-CT for that case (i.e. each student has four PBL-CT scores, one corresponding to each case); in addition, a total PBL-CT score was found by summing the four case scores. Any posts by students who did not complete the course were not considered in the analysis.

IBM SPSS 19.0 was used for all statistical calculations. ANOVA analysis with Fisher's Least Significant Difference Test was used for ad hoc comparisons of cohort means within the distance or blended programs. Comparisons of means between programs (combined distance cohorts versus combined blended cohorts) used independent samples *t*-tests. Correlation analysis was used to examine the relationships between the PBL-CT and FE-PBL scores; the collaboration indicators; and the social, moderator and cohesive indicators. Graphs were generated where appropriate using Microsoft Excel 2007.

### ***Qualitative component.***

A qualitative approach was used to help answer the following research questions:

1. How does the online asynchronous PBL forum activity of distance and blended students differ? How does this activity change over time?
2. In what ways do the levels of critical thinking observed in students from distance and blended courses differ in similar online PBL situations? What elements influence this?
4. Is there evidence that student posts containing critical thinking indicators affect the participation of students in following posts?
5. Is critical thinking more apparent in subjects where students have more prior work experience? How do students with more work experience use that experience within the group discussion? Do they use it to scaffold the critical thinking of their group?
6. What types of scaffolds are used most by students? Are there differences in use across students from distance and blended courses? Is there evidence in the discussion posts that the scaffolds used by students support their critical thinking?

The qualitative research took place in two interconnected phases: the thread maps and content analysis; followed by the interviews (see Figure 2). The results of the thread maps and content analysis were used to develop the interview questions. The results of the interviews were then used to support the interpretations of some of observations of the thread maps and content analysis.

#### *Thread maps.*

Thread maps were constructed for each team and case in a cohort as a hard copy diagram outside of NVivo. This technique was adapted from the work of Levin, Kim, & Riel (1990), and involves constructing a graphic representation of how an asynchronous online discussion occurs over time (Pena-Shaff & Nicholls, 2004). While the construction of the thread maps occurred alongside the data coding using the Cofl indicators, the thread maps were not a coding procedure. The utility of the thread maps was that the entire organization of the discussion can be observed with the Cofl coding highlighted.

In each thread map, a line on the diagram represents an online discussion forum post. Each post is recorded with title of the post, the author's name, date and time of

posting, as well as the length of the post (expressed as the number of lines of text in the body of the post). Posts that initiated a thread are left justified on the diagram. Replies to a post are indented below the post and connected by an arrow. The Cofl cognitive domain coding of the posts was represented with one of five colours to show the categories to which the post belonged (see Figure 5 Results for an example). Note that although the Cofl coding was done in NVivo, the thread maps also captured this coding to support a visual analysis of the learners' engagement. The thread maps were examined for patterns which indicated how the group was working together, as well as any patterns between the appearance of Cofl indicators and time, or the use of scaffolds by students. The patterns that were observed were compared to the content of the posts to try to determine the meaning of the observed patterns. In some cases, the observed patterns resulted in questions that were addressed where possible during the interview phase (see Appendix A for a list of questions).

#### *Content analysis.*

An open coding approach was used to look for evidence of the kinds of scaffolds being used by students to support their learning as well as evidence of collaboration occurring between students. This approach was applied independently from the Cofl coding, although some comparisons between the Cofl coding and the collaboration and scaffolds coding will be discussed in the results and discussion. The codes were derived solely from the data, and coding for the content analysis was done in NVivo. As a post could potentially include several examples of different collaborative behaviours or use of several different learning scaffolds, the sentence and sentence fragment was the unit of analysis for this stage of the content analysis. Evidence of scaffolds included examples such as the use of source materials (use of websites, textbooks, etc.) as well as just-in-time teaching presence, and answers to questions directed to the investigator. Evidence of collaborative work included examples such as organizational moves, posting templates, directional sign posts for things that have been posted to collaborative workspaces like wiki, Google docs, Writerly, etc., as well as items like MSN logs, exchanging of phone numbers and Skype ids.

Following the content analysis steps described above, frequency counts of each type of learning scaffold, collaboration indicator or social indicator were done using

NVivo queries. The frequency counts underwent quantitative analysis as described above using SPSS.

### *Interviews.*

Invitations to participate in interviews were sent out via email to the members of the blended 2010-2011 cohort as well as the members of the distance 2010 cohort. The members of each cohort that returned signed consent forms and agreed to participate in the interviews were interviewed either in person or via telephone.

All interviews were recorded using a Zoom H2 Handy Recorder to generate MP3 files. The digital recordings were transcribed into word documents by a transcription service, and proofed against the recordings prior to analysis. The transcript of each interview was sent to the appropriate interviewee to validate the transcription and to allow them to confirm their continued willingness to have their interview responses included in the study. All participants indicated that they were willing to continue and that the transcripts accurately reflected their responses to the questions. None of the interviewees indicated that there were any corrections or alterations needed for their interview transcripts. The semi-structured interview questions and prompts can be found in Appendix A. Once verified, the transcripts were moved into the NVivo10 software to assist in the analysis.

An open coding approach was taken to the analysis of the interview data. Interview responses were examined looking for themes as well as for illustrative exemplar quotes to support the results and interpretations of the thread maps and content analysis.

### **Concluding Remarks**

This study used a mixed methods design to address the research questions. The quantitative component allowed the FE-PBL and PBL-CT scores to be compared both within the distance and blended groups as well as between the distance and blended groups. The results of the quantitative analyses and qualitative thread map and content analyses were used to support the development of the questions for the interviews. The content analysis, thread maps and interview data came together to support the

development of a more complete picture of how the students and their teams participated in online PBL discussions. The results will be discussed in chapter four.

## **Chapter 4 Results**

This chapter describes the results of this study. The study populations and data sources for the study are described, as well as the addition of a category to the Cofl cognitive presence categories to account for organizational posts. This is followed by a series of results that describe the variability of the cohorts that make up the distance and blended groups with respect to their FE-PBL and PBL-CT scores, how they changed over time, and in response to instructional changes. The next sections describe the use of the thread maps and content analysis to highlight the similarities and differences between student participation in the two programs in terms of their online behaviours during a multi-phase online problem-based learning exercise; as well as patterns of posting behaviour that provide evidence for how students are working together. The content analysis section includes a discussion of the development of the Collaboration and Learning Scaffolds (CLS) coding system that allows investigators to assess both collaborative interactions within teams as well as use of the literature by their students to scaffold their learning. The chapter concludes with a section that summarizes the interview results. The implications and interpretation of these results will be presented in chapter five.

### **Study Populations and Data Sources**

As noted in the methods section, there are two major sources of data for this study: archived compiled asynchronous online discussion forums and interviews. This section will first describe the study populations (distance and blended), and will then describe how these populations are distributed within the two data sources (discussion forums and interviews). Comparisons were made between distance and blended students to highlight similarities and differences between the students in the two programs in terms of their online behaviours during a multi-phase online problem-based learning (PBL) exercise. Both programs use asynchronous discussion forums for the PBL exercise that are located in a Moodle-based course shell.

**Study populations.**

This section provides details about the cohorts that are the focal point for this study. Further details about the programs that the distance and blended students are enrolled in is available in the Educational Context section of chapter one.

***Distance students.***

The distance students at RRU are typically in their late twenties or early thirties, with 55% of students aged 26 to 35, with a mean age of 32 (Royal Roads University, 2011). They have significant environmental work experience and are pursuing their degree with a view to progressing to management positions with their employer (Royal Roads University, 2013a). This population included members of the 2004, 2006, 2008, and 2010 cohorts of the BSc Environmental Management program at Royal Roads University, with a total enrollment of 109 students. One student's data was eliminated from the 2006 cohort because the student dropped the course prior to writing the final exam. This resulted in a final group size of 108 students with 55 males and 53 females. The distance students used online instruction for ENSC 407 Ecotoxicology, including the problem-based learning activity. Note: this program is offered biannually.

***Blended students.***

The blended students are typically 22 - 24 years old, with 60% of students aged 19-25 with a mean age of 24 (Royal Roads University, 2011). These students are usually either changing fields into environmental science, or are looking to complete their undergraduate education before going out to work, often for the first time in the environmental field (Royal Roads University, 2012). This population included members of the 2004-2005, 2006-2007, 2009-2010 and 2010-2011 cohorts of the BSc Environmental Science program at Royal Roads University, with a total enrollment of 156 students. The majority of the instruction for ENSC 407 Ecotoxicology for the blended cohorts was done in a face-to-face format, with the problem-based learning portion of the course occurring in asynchronous online discussion forums.

One student's data was eliminated as they dropped the course prior to writing the final exam. There was also a technical problem that resulted in missing data. Two of seven teams were omitted from the data set of the 2009 cohort due to problems with

downloading and compiling data that generated HTML files with incomplete records of discussion forums—that resulted in the loss of 12 participants. An attempt was made to recover these records, but it was not possible to do so because of a change in the Moodle platform combined with a major change in the RRU server infrastructure. To determine whether the loss of these 12 participants changed the cohort grade distribution, the cohort mean score on the final exam was compared for the 2009 cohort with ( $N = 40$ ) and without those 12 participants included ( $N = 28$ ). The class mean changed from 74.05 points ( $N = 40$ ) to 74.00 points ( $N = 28$ ), suggesting that the elimination of those participants had a limited effect on the cohort mean scores, and thus did not preferentially remove scores from either the top or bottom of the class grade distribution. This resulted in a final sample size of 144, with 71 males and 73 females.

The blended students begin their program in the fall of one year and finish in the summer of the following year. For the sake of clarity in this document, the cohorts will be referred to using the year that they began their program – that is, the blended 2004-2005 cohort will be referred to as the blended 2004 cohort. Note that although the blended program is offered annually, the cohorts in these academic years were chosen because they could be paired with the distance cohorts who worked with the same version of the online PBL activity. Although the problems share similar features from year to year, the instructional materials, assignments and PBL activity are updated yearly, with the PBL problems being cycled every four academic years. As a result, the 2006 and 2010 blended cohorts shared the same PBL problems.

### **Data sources.**

The two populations of students described above both contributed to the two different data sources as described below. These data sources were used differently, and had different requirements for ethical approval and participant consent.

### ***Archived discussion forums.***

This data source included all discussion posts by members of the distance and blended student cohorts. For four distance cohorts, this was a total of 8313 posts

distributed across 797 threads by 15 teams. For the four blended cohorts, this was a total of 3671 posts distributed across 919 threads by 19 teams.

### ***Interviews.***

Interviewees were recruited by sending email invitations to the 34 members of the 2010 distance cohort, and the 46 members of the 2010 blended cohort. The email invitations explained the study and included the consent form as an attachment. Full informed consent was sought for participation in interviews as well as the use of quotations from the interview transcripts from each interviewee (see Appendix A for a copy of the participant invitations and consent forms). Two male students from the distance cohort (Dean and Don) agreed to be interviewed by telephone. One female student (Bev) and one male student (Bob) from the blended cohort agreed to be interviewed. Bev was interviewed by telephone, while Bob was interviewed in person. The four interviews ranged in length from 26.5 minutes to 40 minutes. For a list of interview questions, please see Appendix A. All interviewees confirmed that the transcripts accurately reflected their responses and their continued participation in the study. No corrections were required for any of the transcripts by the interviewees.

### **Quantitative Component**

The first section includes a description of the initial coding of the 2004 distance and blended archived discussion forums using the Cofl cognitive presence categories and how that coding resulted in the addition of a new category to capture organization posts, as well as comments on the consistency of coding. The next section contains the analysis of the variability of the mean FE-PBL and PBL-CT scores between the cohorts that make up the distance and blended groups, as well as between the distance and blended groups. This is followed by comparisons between the distance and blended groups with respect to posting behaviours and the behavioural indicators of the Cofl cognitive presence categories.

### **Archived discussion forums - initial coding adjustments.**

Team discussion forums were downloaded and treated as described in the Methods section. Each team had a separate discussion forum for each case problem (four

cumulative case problems per team) which resulted in 60 compiled files for the distance cohorts (15 teams) and 76 compiled HTML files for the blended cohorts (19 teams). Team size varied between six and eight members, depending on the cohort size. The discussion forum posts for each PBL discussion were coded using the four categories for cognitive presence (triggering, exploration, integration and resolution) described in the Cofl framework (Garrison et al., 2001).

Similar to the work of Meyer (2003) and Garrison et al. (2001) on cognitive presence in online discussions, an "other" category was used to capture posts that did not otherwise fit into the cognitive presence categories. It soon became apparent that a large number of posts were being coded to "other" during the content analysis. When the "other" category posts were examined, it appeared that many of these posts either organized the discussion itself or negotiated how the team was to work together. For example, many discussions included a series of posts that set up the outline of the discussion using the text of the hard scaffolds provided in the cases. Students would then reply to these posts, causing threads to form under these "headings". The "other" posts also captured when students posted action plans, proposed templates to organize the information that was collected on various topics, or volunteered to take on specific tasks. As these activities seemed related to the approaches taken by teams to online PBL, and in many cases required thinking and planning, a category "organization" was added to the cognitive presence coding scheme to capture these posts. The addition of this category greatly reduced the number of "other" posts, and provided information on how the teams were working together.

The resolution category (testing and defending solutions, applications to real world situations; Garrison et al., 2001) was adjusted to better fit the context of this PBL activity. The posting of drafts of the final report was included in the resolution category as this was a method of testing solutions among team members. Changes to these drafts that only included spelling, grammar and formatting changes were not considered as resolution posts, and were coded as organization or integration posts, depending on the degree of changes from the previous draft.

Coding began with the blended 2004 cohort. Posts were straightforward to assign to the various categories. When a post seemed to potentially fit into more than

one category, the coding up/coding down approach used by Garrison et al. (2001, p. 17) was adopted as described in the Methods section. There were very few instances overall where coding down was required. In most cases, the indicators of the behaviours were clear enough to allow for coding up.

This study is an example of a self-study. As a result, all posts were coded by the investigator, so inter-rater reliability could not be checked in this study. However, similar to the approach taken by Rourke et al. (2001), selected discussions were re-coded at various points in the coding process to check the consistency of coding over time. The posts for the distance 2004 and blended 2004 cohorts were re-coded on two separate occasions after the initial coding was done on all the cohorts' posts (the organization category was included). The first time was near the start of the coding process, as the secondary coding scheme for learning scaffolds used by students was being developed. The second re-coding occurred near the end of the coding process when these cohorts were re-examined for the citations contained in attachments to posts (see NVivo and Manual Coding of Attachment Citations section below). The coding consistency was very robust over time. There were only 12 instances of codes being altered the first time the cohorts were re-coded; four of 1311 posts in the 2004 distance cohort discussion forums, and eight of 492 posts in the 2004 blended cohort discussion forums. During the second re-coding, no codes were altered for either the distance or blended cohorts.

### **Variation within distance and blended groups.**

Initial comparisons of final exam scores, as well as the number of posts that represented critical or higher order thinking for each student, were made to determine how similar the individual cohorts were to one another within the two larger groups (blended and distance).

### ***Final exam scores (FE-PBL).***

The final exam in the course consists of two parts - a multiple choice/long answer portion (answers of 50-250 words), and a scenario-based portion that was designed to be similar to the PBL cases used in the course. As the PBL portion of the course is the focus of this study, the cohorts were compared based on their mean scores on the PBL-like scenario portion of the final exam (FE-PBL) to examine the variability between the

cohorts that make up the distance or blended group (see Tables 2 and 4, respectively). Because the marks distribution and some of the other course deliverables varied between the distance and blended classes, a comparison of overall course performance was not done. However, an independent samples t-test comparison of the mean distance and blended cohorts for the entire final exam showed no significant difference ( $t(250) = 1.78, p = 0.077$ ) with means of 75.8% and 78.8% for distance and blended teams respectively.

Table 2 *Descriptive Statistics for FE-PBL Scores for Four Cohorts of Distance BSc Students During an Ecotoxicology Course*

	<i>N</i>	Mean *	Std. Deviation
2004 cohort	21	90.75	7.76
2006 cohort	23	80.22	11.78
2008 cohort	30	76.29	13.10
2010 cohort	34	78.37	12.81
Total	108	80.59	12.80

\* FE-PBL scores are scores out of 110 total possible points.

Table 3 *ANOVA Analysis of the Mean FE-PBL Scores for Four Cohorts of Distance BSc Students during an Ecotoxicology Course*

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Between groups	3	2894.30	964.77	6.85	0.000
Within groups	104	14649.91	140.87		
Total	107	17544.22			

An ANOVA test of the FE-PBL cohort score means showed that at least one of the distance cohort FE-PBL score means was not equal to the rest ( $p < 0.001$ ; see Table 3). The Fisher Least Significant Difference post hoc test demonstrated that the mean FE-PBL score of the 2004 cohort was significantly different at the  $p < 0.05$  level from that of the 2006, 2008 and 2010 cohorts, which were not significantly different from one another (see Table B1 in Appendix B).

Similar to the distance cohorts, an ANOVA analysis was used to compare the cohort means of the FE-PBL scores for the blended cohorts. The ANOVA analysis of the mean FE-PBL scores demonstrated that at least one of the blended cohort mean scores was not equal to the others (see Table 5). A Fisher Least Significant Difference post hoc test indicated that the mean FE-PBL scores for the 2004 cohort and 2009 cohort are significantly different from all other cohorts in this group at the  $p < 0.05$  level. The mean FE-PBL scores for the 2006 cohort are significantly different from the 2004 and 2009 cohorts, but not from the 2010 cohort at the  $p < 0.05$  level (see Table B2 in Appendix B).

Table 4 *Descriptive Statistics for FE-PBL Scores for Four Cohorts of Blended BSc Students During an Ecotoxicology Course*

	<i>N</i>	Mean *	Std. Deviation
2004 cohort	30	87.92	10.48
2006 cohort	40	80.49	14.21
2009 cohort	28	74.05	9.93
2010 cohort	46	81.49	9.55
Total	144	81.10	12.01

\* FE-PBL scores are scores out of 110 total possible points

Table 5 *ANOVA Analysis of the Mean FE-PBL Score for Four Cohorts of Blended BSc Students during an Ecotoxicology Course*

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Between groups	3	2808.22	936.07	7.35	0.000
Within groups	140	17825.16	127.32		
Total	143	20633.37			

### ***PBL critical thinking scores (PBL-CT).***

Critical or higher order thinking for each student in the discussion posts was quantified based on coding of the discussion posts to the exploratory, integration, and resolution categories of the community of inquiry model. Garrison et al. (2001) and

Meyer (2003) agree that the categories of exploration, integration and resolution exhibit higher-order thinking skills (critical thinking) because such posts involve the students in activities such as brainstorming, creating solutions, defending ideas, and constructing knowledge. The number of posts categorized as exploration, integration and resolution were totalled for each student across all four PBL cases, and this total was used as their PBL critical thinking (PBL-CT) score.

The student's mean PBL-CT scores for the cohorts were compared to examine the variability between the cohorts within the groups (distance and blended). Table 6 shows the descriptive statistics comparing the student's mean PBL-CT scores for the four distance cohorts. The cohort mean scores appeared similar. The 2008 cohort had the largest variance (see Table 6). An ANOVA test demonstrated that the cohort mean PBL-CT scores were equal for the four distance cohorts at the  $p < 0.05$  level (see Table 7).

Table 6 *Descriptive Statistics for PBL-CT Scores for Four Cohorts of Distance BSc Students in an Online PBL Activity During an Ecotoxicology*

	<i>N</i>	Mean	Std. Deviation
2004 cohort	21	29.00	12.35
2006 cohort	23	32.87	16.83
2008 cohort	30	37.47	21.52
2010 cohort	34	32.62	13.96
Total	108	33.31	16.76

Table 7 *ANOVA Analysis of the Mean PBL-CT Scores for Four Cohorts of Distance BSc Students in an Online PBL Activity During an Ecotoxicology Course*

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Between groups	3	929.19	309.73	1.11	0.350
Within groups	104	29130.11	280.10		
Total	107	30059.30			

Table 8 shows the descriptive statistics comparing the mean PBL-CT scores for the blended cohorts. The 2009 and 2010 cohorts had larger means and variances

than the 2004 and 2006 cohorts (see Table 8). An ANOVA analysis indicated that at least one of the PBL-CT score means was not equal to the others (see Table 9). A Fisher Least Significant Difference post hoc test indicates that there was no significant difference between the 2004 cohort and the 2006 cohorts ( $p = 0.100$ ), and that there was no significant difference between the 2009 and 2010 cohorts ( $p = 0.324$ ). However, the two earlier cohorts were significantly different from the two later cohorts ( $p < 0.001$ ) with respect to their student's mean PBL-CT scores (see Table B3 in Appendix B).

*Table 8 Descriptive Statistics for PBL-CT Scores for Four Cohorts of Blended BSc Students in an Online PBL Activity During Ecotoxicology Course*

	<i>N</i>	Mean	Std. Deviation
2004 cohort	30	12.43	5.30
2006 cohort	40	9.45	5.45
2009 cohort	28	25.75	10.19
2010 cohort	46	27.52	8.19
Total	144	19.01	11.02

*Table 9 ANOVA Analysis of the Mean PBL-CT Scores for Four Cohorts of Blended BSc Students in an Online Problem-Based Learning Activity during an Ecotoxicology Course*

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Between groups	3	9557.98	3185.99	57.19	0.000
Within groups	140	7799.10	55.714		
Total	143	17357.97			

### **Comparison of FE-PBL and PBL-CT scores between distance and blended groups.**

The mean FE-PBL scores and the mean PBL-CT scores for the distance and blended groups were compared using independent samples *t*-tests. The purpose of the comparison was to see if the two groups were achieving differently in the course as reflected by their mean FE-PBL score, and to see if their online posts reflected a different level of critical thinking as reflected by their mean PBL-CT scores.

***FE-PBL scores between distance and blended groups.***

The comparison of the distance and blended program's mean FE-PBL scores (across all cohorts) showed that the students in the distance program achieved a mean of 80.59 points compared to a mean of 81.10 points for the blended program with standard deviations of 12.80 and 12.01 respectively (see Table B4 in Appendix B). The Levene test for the equality of variances demonstrated that the variances are equal. An independent samples *t*-test indicated that the differences in the distance and blended student's mean FE-PBL scores were not significant (see Table 10).

Table 10 *Independent Samples t-test Analysis of the Mean FE-PBL Scores for Distance Versus Blended BSc Students during an Ecotoxicology Course*

	<i>t</i>	<i>df</i>	<i>p</i> (2-tailed)
Final Exam Score	0.32	250	0.747

***PBL-CT scores.***

Comparison of the mean PBL-CT score between the distance and blended groups showed that distance students had a mean score of 33.31 posts compared to a mean of 19.01 posts for blended students with standard deviations of 16.76 and 11.02 respectively (see Table 11). Levene's test for equality of the variances demonstrated that the variances were not equal. An independent samples *t*-test demonstrated that the mean PBL-CT score was significantly higher for the distance group than the blended group across all cohorts (see Table 12). The Cohen's *d* for this difference is very large at 1.30 standard deviations. Because of the obvious difference in the PBL-CT scores between the 2004 and 2006 cohorts and the later blended cohorts (2009 and 2010), the distance cohorts were also compared to the later blended cohorts using a separate independent samples *t*-test. Even when comparing these more similar cohorts, the *t*-test result demonstrated that the mean PBL-CT score was still significantly higher for the distance group than the blended group.

Table 11 *Descriptive Statistics for PBL-CT Scores for Distance and Blended BSc Students in an Online PBL Activity During Ecotoxicology Course*

	Program enrolled	N	Mean	Std. Deviation
PBL critical thinking score	Distance	108	33.31	16.76
	Blended	144	19.01	11.02

Table 12 *Independent Samples t-Test Analysis of the Mean PBL-CT Scores for Distance versus Blended BSc Students in an Online Problem-Based Learning Activity during an Ecotoxicology Course*

	t	df	p (2-tailed)
PBL-CT score	-7.71	173.92	0.000

#### **Correlation between FE-PBL scores and PBL-CT scores.**

The PBL-CT score is an index of the higher order thinking that students exhibit by posting exploration, integration and resolution posts, while the FE-PBL score is an index of higher order thinking that students exhibit by how well they are able to analyze a scenario and apply their knowledge. Since both the PBL-CT score and performance on the FE-PBL could both be considered as independent indices of higher order thinking, a Pearson correlation was calculated to see if the two indices varied together using students' individual scores on both indices - across all students in both groups. It was determined that there was no correlation between the two measures ( $r(250) = 0.072$ ,  $p=0.256$ ) (see Table B5). If the correlational analysis is run based on all distance cohorts and the 2009 and 2010 blended cohorts, which are more similar to the distance cohorts (see Figure 4), the correlation becomes significant ( $r(182) = 0.186$ ,  $p=0.012$ ).

#### **Distance versus blended posts, threads and posts per thread.**

The initial read-through of the discussion forums gave the impression that the distance cohorts posted more messages to the discussion forum, and were more likely to be exchanging ideas than the blended cohorts. The blended cohorts' discussion

forums gave the impression of being a place that teams used to assemble information rather than discuss and build on ideas. To quantitatively test these ideas, the distance and blended teams were compared using independent samples *t*-tests with respect to the mean number of posts per case, the mean number of threads that those posts were organized into, and the mean number of posts per thread (i.e. the mean length of the thread) (see Table 13 and 14).

The *t*-tests confirmed the following: that the distance teams posted significantly more messages per case problem discussion than blended teams; that the mean number of threads in use per case was not significantly different; and that the distance teams used significantly longer threads in their discussions than blended teams (see Tables 13 and 14)

Table 13 *Descriptive Statistics for Posts, Threads and Mean Posts Per Thread for Distance and Blended BSc Teams Per Case in an Online PBL Activity During an Ecotoxicology Course*

	Program	N	Mean	Std. Deviation
Total posts per case	Distance	60	138.55	48.13
	Blended	76	48.30	26.36
Total threads per case	Distance	60	13.28	5.56
	Blended	76	12.09	6.27
Mean posts per thread per case	Distance	60	11.43	4.37
	Blended	76	5.06	3.44

Table 14 *Independent Samples t-test for Posts, Threads and Mean Posts Per Thread for Distance Versus Blended BSc Teams Per Case in an Online Problem-Based Learning Activity during an Ecotoxicology Course*

	<i>t</i>	<i>df</i>	<i>p</i> (2-tailed)
Total posts per case	-13.06	86.43	0.000
Total threads per case	-1.16	134	0.250

Average posts per thread per case	-9.52	134	0.000
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### Distance versus blended counts of Cofl cognitive presence indicators.

The mean number of posts per case in the organization, exploration, integration, resolution, and other categories were all significantly higher for the distance teams than for the blended teams (see Table B6 and Figure 3). Figure 3 shows a graphical summary of the data from Table B6. The much higher number of posts per case by the distance teams was particularly apparent. The graph also highlights the significantly higher activity by the distance teams in all categories except triggering, where no significant difference was observed (see Figure 3).

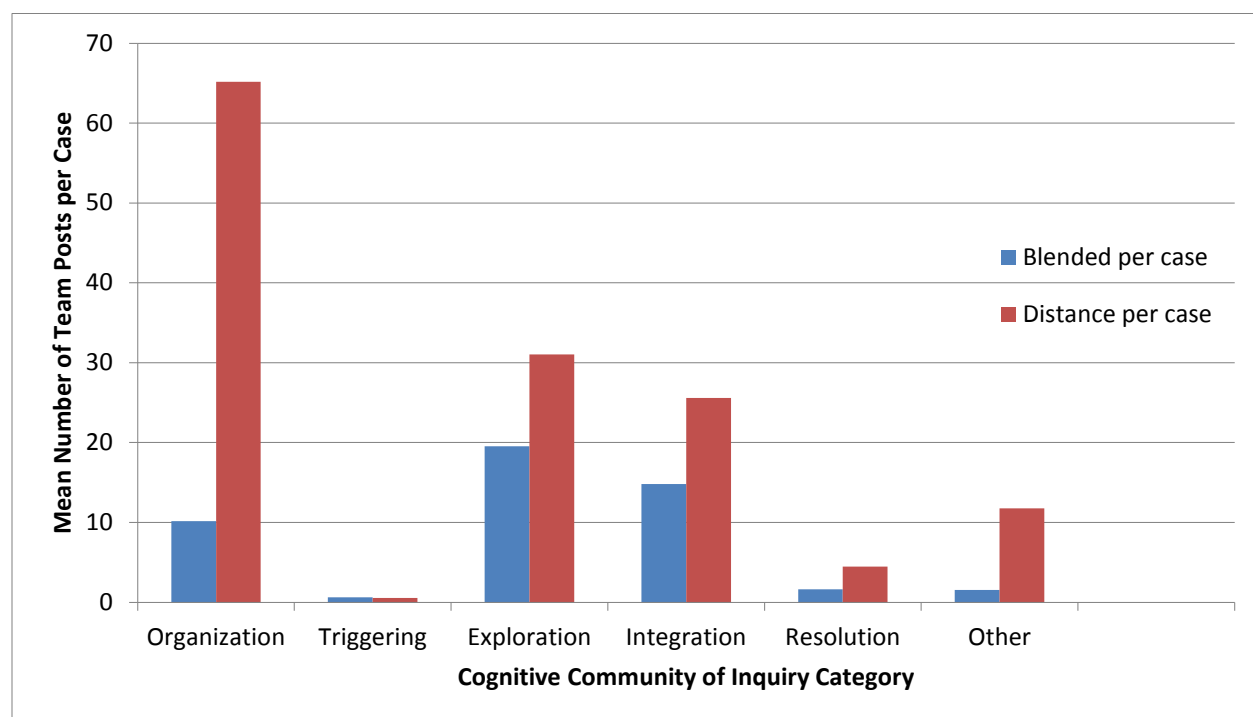


Figure 3. Mean number of team posts for the Cofl cognitive categories for distance and blended teams.

The Levene's test for equality of variances indicated equality in the variances for the categories of triggering, exploration and resolution but that the variances for the categories of organization, integration and other were not equal ( $p < 0.05$ ). An

independent samples *t*-test demonstrated that for all categories except for the triggering category, the distance teams posted more messages than the blended teams per case ( $p < 0.001$ ) (see Table 15). Cohen's *d* values indicated that the differences between the mean number of posts for each case problem by the distance and blended teams were large to extremely large (see Table 15).

Table 15 *Independent Samples t-test for Counts of Cognitive Community of Inquiry Indicators for Distance Versus Blended BSc Teams Per Case in an Online Problem-Based Learning Activity during an Ecotoxicology Course*

	<i>t</i>	<i>df</i>	<i>p</i>	Cohen's <i>d</i>
Organization	-16.68	68.00	0.000	7.20
Triggering	0.48	134	0.633	-
Exploration	-4.17	134	0.000	0.75
Integration	-5.75	112.03	0.000	1.13
Resolution	-7.12	134	0.000	1.43
Other	-11.45	80.21	0.000	3.30

#### **PBL-CT score comparisons across case one to four.**

As noted previously the PBL-CT score was calculated as the sum of posts categorized as exploration, integration and resolution for each student across all four case problems. It was possible that this score might have changed over time, as the students progressed through the four part cumulative case study. To test this idea, a comparison of mean PBL-CT scores for each case problem was made within the distance and blended groups, to determine how similar the individual cohorts were to one another within the two programs for each case problem. The purpose of the comparison was to see if the PBL-CT scores changed as students became more experienced with PBL and the amount of scaffolding provided in the problem was reduced.

#### ***Distance cohorts.***

Table 16 and Figure 4 show the descriptive statistics comparing the students' mean PBL-CT score for a typical student in each of the four distance cohorts for each of the four PBL case problems. For each case, the means were fairly close and showed

similar standard deviations. The PBL-CT score means and standard deviations for case two had a larger spread than those of the other cases (see Table 16). The Levene equality of variance test demonstrated that the variances were equal for all four cohorts during case problems one, three and four. In agreement with the apparent wider spread of the means for case problem two, it demonstrates an unequal variance among the four cohorts ( $p < 0.05$ ). An ANOVA test was used to determine whether or not the cohort mean PBL-CT scores for each case were equal for the four cohorts. The results of the ANOVA analysis were not significant at the  $p < 0.05$  level (see Table 17); demonstrating that the PBL-CT scores for typical distance students remained relatively consistent between the four distance cohorts for each case problem.

Table 16 *Descriptive Statistics for Students' PBL-CT Scores Across Four Cases for Four Cohorts of Distance BSc Students in an Online PBL Activity During an Ecotoxicology Course*

		<i>N</i>	Mean	Std. Deviation
Case 1	2004 cohort	21	7.14	3.88
	2006 cohort	23	7.48	5.75
	2008 cohort	30	9.97	5.41
	2010 cohort	34	7.76	5.16
	All cohorts	108	8.19	5.20
Case 2	2004 cohort	21	6.52	3.84
	2006 cohort	23	9.09	7.58
	2008 cohort	30	12.00	11.27
	2010 cohort	34	10.76	6.64
	All cohorts	108	9.93	8.15
Case 3	2004 cohort	21	9.48	4.93
	2006 cohort	23	8.26	5.29
	2008 cohort	30	9.03	5.12
	2010 cohort	34	7.35	4.51
	All cohorts	108	8.43	4.94
Case 4	2004 cohort	21	5.86	4.37
	2006 cohort	23	8.04	4.39
	2008 cohort	30	6.47	6.07
	2010 cohort	34	6.74	4.63
	All cohorts	108	6.77	4.97

Table 17 ANOVA Analysis of PBL-CT Scores Across Four Cases for Four Cohorts of Distance BSc Students in an Online PBL Activity During an Ecotoxicology Course

		<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Case 1	Between groups	3	135.52	45.17	1.70	0.171
	Within groups	104	2757.40	26.51		
	Total	107	2892.92			
Case 2	Between groups	3	412.23	137.41	2.13	0.101
	Within groups	104	6701.18	64.43		
	Total	107	7113.41			
Case 3	Between groups	3	74.00	24.67	1.01	0.390
	Within groups	104	2532.40	24.35		
	Total	107	2606.41			
Case 4	Between groups	3	57.60	19.20	0.77	0.511
	Within groups	104	2581.61	24.82		
	Total	107	2639.21			

***Blended cohorts.***

Table 18 and Figure 4 show the descriptive statistics comparing the students' mean PBL-CT score for a typical student in each of the four blended cohorts for each of the four PBL case problems. For each case, the means were fairly close for the two earlier cohorts (2004 and 2006) and for the two later cohorts (2009 and 2010); however a difference was observed between the earlier and later cohorts (see Table 18).

Table 18 *Descriptive Statistics for PBL-CT Scores Across Four Cases for Four Cohorts of Blended BSc Students in an Online PBL Activity During an Ecotoxicology Course*

		N	Mean	Std. Deviation
Case 1	2004 cohort	30	3.73	3.24
	2006 cohort	40	3.50	2.32
	2009 cohort	28	7.11	3.27
	2010 cohort	46	6.87	1.94
	All cohorts	144	5.33	3.11
Case 2	2004 cohort	30	3.80	2.54
	2006 cohort	40	2.80	2.02
	2009 cohort	28	6.14	2.75
	2010 cohort	46	6.65	2.79
	All cohorts	144	4.89	3.01
Case 3	2004 cohort	30	2.33	1.63
	2006 cohort	40	1.48	1.55
	2009 cohort	28	6.21	4.14
	2010 cohort	46	8.02	3.55
	All cohorts	144	4.67	4.06
Case 4	2004 cohort	30	2.57	1.52
	2006 cohort	40	1.68	1.69
	2009 cohort	28	6.29	5.22
	2010 cohort	46	5.98	3.29
	All cohorts	144	4.13	3.74

The Levene equality of variance test demonstrated that the variances were not equal for all four cohorts during cases one, three, and four, at  $p < 0.05$  level. An ANOVA test was used to determine whether or not the cohort mean PBL-CT scores for each

case were equal for the four cohorts. The results of the ANOVA were significant at the  $p < 0.05$  level for each case (see Table 19). A Fisher Least Significant Difference post hoc test indicated that for case problems one, two, and four, the mean PBL-CT scores for the blended cohorts are effectively split into two groups, as the earlier cohorts (2004 and 2006) were not significantly different from one another, and the two later cohorts (2009 and 2010) were not significantly different from one another, at the  $p < 0.05$  level (see Table 20). The earlier and the later cohorts were significantly different at the  $p < 0.05$  level in their mean PBL-CT scores for cases one, two, and four (see Table 20). For case problem three, the relationship between the earlier cohorts is the same as it was for case problems one, two, and four, with there being no significant difference between the mean PBL-CT scores for the 2004 cohort and the 2006 cohorts at the  $p < 0.05$  level. However for case problem 3, there were also significant differences between the 2009 and 2010 cohorts at the  $p < 0.05$  level (see Table 20).

Table 19 ANOVA Analysis of the Mean PBL-CT Scores Across Four Cases for Four Cohorts of Blended BSc Students in an Online Problem-Based Learning Activity during an Ecotoxicology Course

		<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Case 1	Between groups	3	407.90	135.97	19.59	0.000
	Within groups	140	971.76	6.94		
	Total	143	1379.66			
Case 2	Between groups	3	397.16	132.39	20.62	0.000
	Within groups	140	899.06	6.42		
	Total	143	1296.22			
Case 3	Between groups	3	1155.67	385.22	44.93	0.000
	Within groups	140	1200.33	8.57		
	Total	143	2356.00			
Case 4	Between groups	3	601.66	200.55	20.04	0.000
	Within groups	140	1400.83	10.01		
	Total	143	2002.49			

Table 20 Fisher's Least Significant Difference Test for the ANOVA Analysis PBL-CT Scores Across Four Cases for Four Cohorts of Blended BSc Students in an Online PBL Activity During an Ecotoxicology Course

Dependent Variable	(I) cohort membership	(J) cohort membership	Mean Difference (I-J)	<i>p</i>
Case 1	2004 cohort	2006 cohort	0.23	0.714
		2009 cohort	-3.37*	0.000
		2010 cohort	-3.14*	0.000
	2006 cohort	2009 cohort	-3.61*	0.000
		2010 cohort	-3.37*	0.000
	2009 cohort	2010 cohort	0.24	0.707
	Case 2	2004 cohort	2006 cohort	1.00
2009 cohort			-2.34*	0.001
2010 cohort			-2.85*	0.000
2006 cohort		2009 cohort	-3.34*	0.000
		2010 cohort	-3.85*	0.000
2009 cohort		2010 cohort	-0.51	0.403
Case 3	2004 cohort	2006 cohort	0.86	0.227
		2009 cohort	-3.88*	0.000
		2010 cohort	-5.69*	0.000
	2006 cohort	2009 cohort	-4.74*	0.000
		2010 cohort	-6.55*	0.000
	2009 cohort	2010 cohort	-1.81*	0.011
Case 4	2004 cohort	2006 cohort	0.89	0.245
		2009 cohort	-3.72*	0.000
		2010 cohort	-3.41*	0.000
	2006 cohort	2009 cohort	-4.61*	0.000
		2010 cohort	-4.30*	0.000
	2009 cohort	2010 cohort	0.31	0.686

\* The mean difference is significant at the 0.05 level.

Figure 4 shows a graphical summary of the data from Tables 16 and 18. Higher PBL-CT scores can be observed for the distance cohorts as compared to the blended cohorts, as can the split in the scores for the earlier and later blended cohorts (see Figure 4). Figure 4 also shows that for any given cohort, the mean PBL-CT score for a typical student remained relatively consistent across the four PBL case problems.

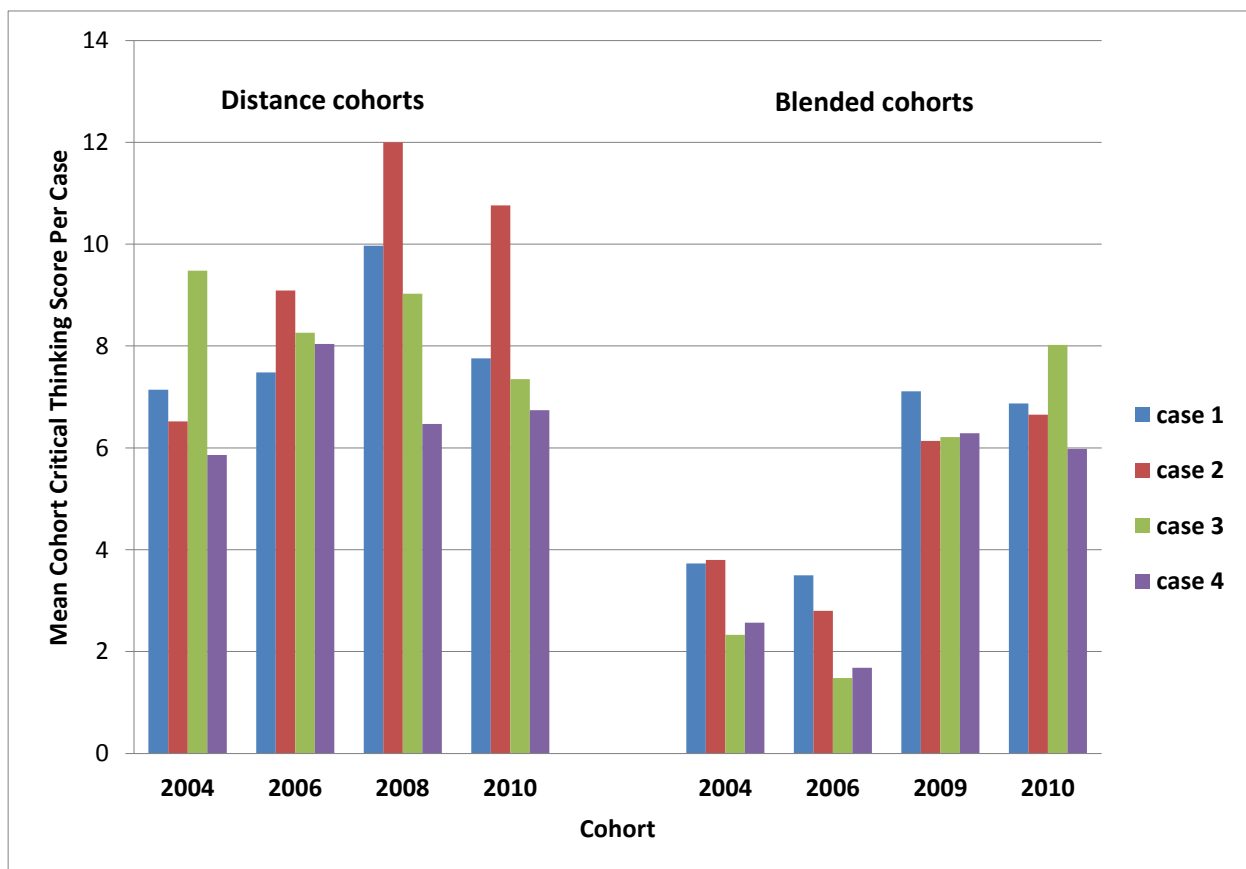


Figure 4. Mean cohort PBL-CT score for a typical student for each case for distance and blended cohorts.

***Distance versus blended PBL-CT score comparisons across case one to four.***

Comparison of the mean student PBL-CT scores for each case between the distance and blended programs showed that distance program students had a higher mean score than the blended program students in all four cases (see Table 21). Levene's test for equality of the variances demonstrated that the distance and blended program variances were not equal for any of the four cases ( $p < 0.05$ ). A series of

independent samples *t*-tests demonstrated that the mean student PBL-CT scores were significantly higher for the distance group than the blended group for each of the four case problems ( $p < 0.001$ ). The Cohen's *d* for the differences in the student mean PBL-CT scores for each case problem were large or very large for all case problems (see Table 22). If the earlier two blended cohorts are removed from the analysis, the conclusion for the first two cases remains the same (distance teams have significantly higher PBL-CT scores than blended teams), but there is no significant difference between the PBL-CT scores for distance and blended teams for case three and four.

Table 21 *Descriptive Statistics for Student PBL-CT Scores Across Four Cases for Distance Versus Blended BSc Students in an Online PBL Activity During an Ecotoxicology Course*

	Program	N	Student	
			Mean	Std. Deviation
Case 1	Distance	108	8.19	5.20
	Blended	144	5.33	3.11
Case 2	Distance	108	9.93	8.15
	Blended	144	4.89	3.01
Case 3	Distance	108	8.43	4.94
	Blended	144	4.67	4.06
Case 4	Distance	108	6.77	4.97
	Blended	144	4.13	3.74

Table 22 *Independent Samples t-test for PBL-CT Scores Across Four Case Problems for Distance Versus Blended BSc Students in an Online Problem-Based Learning Activity during an Ecotoxicology Course*

	<i>t</i>	<i>df</i>	Cohen's <i>d</i>
Case 1	-5.091	163.19	0.92
Case 2	-6.115	128.99	1.67
Case 3	-6.447	203.84	0.93
Case 4	-4.620	191.54	0.71

Note: only the *t*-test values based on unequal variances, as reflected by the decreased degrees of freedom are shown.

### **Thread Maps and Content Analysis**

This section describes the results of the thread maps and the content analysis. The content analysis described in this section uses an open coding approach to look for evidence of student collaboration and use of learning scaffolds rather than focussing on critical thinking using the Cofl cognitive presence indicators as described in Quantitative Analysis section above. Both the construction of the thread maps and the content analysis began with a read-through of the online discussion forums for each team, followed by the designated analysis as described in the Methods section. The results of these two parts are outlined separately below.

#### **Thread map analysis.**

The discussion forums were read through and used to construct thread maps for each team and case problem in a cohort as a hard copy diagram outside of NVivo. This was a way of representing how an asynchronous online discussion occurs over time in diagrammatic form so the entire organization and timing of the discussion could be observed with the community of inquiry coding highlighted.

In each thread map, a line on the diagram represented an online discussion forum post. Each post was recorded by the author's name, date and time of posting. As shown in Figure 5, the length of a post was indicated with either a numeral followed by L (indicating the number of lines of text) or an A\* numeral (indicating the number of pages

in an attachment) for each post. Posts that were designated as 0L (see Figure 5, post 5 and 9), did not have any text in the body of the posts. These posts provided an organizational header only. Posts that initiated a thread were left justified on the diagram (e.g., post 1, 5, 9 and 15 in Figure 5 below) and had the title of the post recorded. Replies to a post were indented below the post and connected by an arrow (e.g., post 2 in Figure 5). A thread was defined to be the initial post and all the replies to that initial post (e.g., post 1-4 in Figure 5). All posts were given an identification number, which was added to the diagram at the left side to provide a way to refer to specific posts. The posts were then colour-coded to show which of the cognitive domain CofI categories the post belonged to: organization posts, yellow coding; trigger post, pink coding; explore posts, blue coding; integration posts, green coding; resolution posts, orange coding; and other posts were left white (see Figure 5). The thread maps were examined for patterns that indicated how the group was working together. Any patterns observed were looked at in combination with the content of the posts to determine what the patterns might have represented. All figures of thread maps show pseudo-records with altered names that were created to anonymously represent typical records derived from the online data (see Figures 5 - 12).

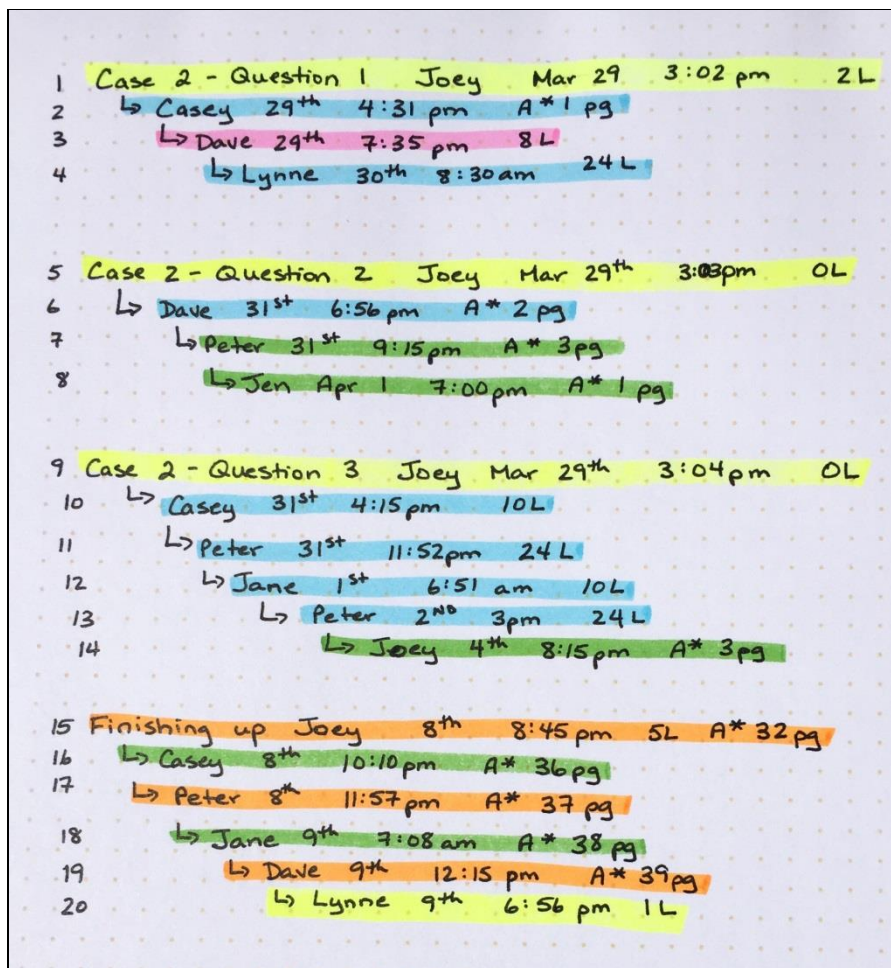


Figure 5. Thread map pseudo-example demonstrating colour-coding of the posts based on the community of inquiry indicators.

### **Getting organized.**

It is not surprising that both blended and distance teams started each PBL case with an organizational meeting to brainstorm their approach, divide up the work and generally identify initial information gaps. In fact, the occurrence of such a meeting was one of the initial impressions from the first read-through of the online discussion forums. For the distanceteams, these asynchronous "meetings" were more overt and directly visible on the discussion forum as a series of organization posts that occurred early in a discussion. In Figure 6 below, notice the first eleven posts (separated into two threads) were colored yellow, indicating that they belonged to the organization category. These posts contained messages about dividing up the work, and organizing what approach to take. In the distancediscussion forums, a collection of organizational posts

like this could also occur later in the discussion. In that context, they appeared to represent a "check in" meeting. These online meetings shared collected information, identified gaps that remained to be filled and divided the remaining work among team members.

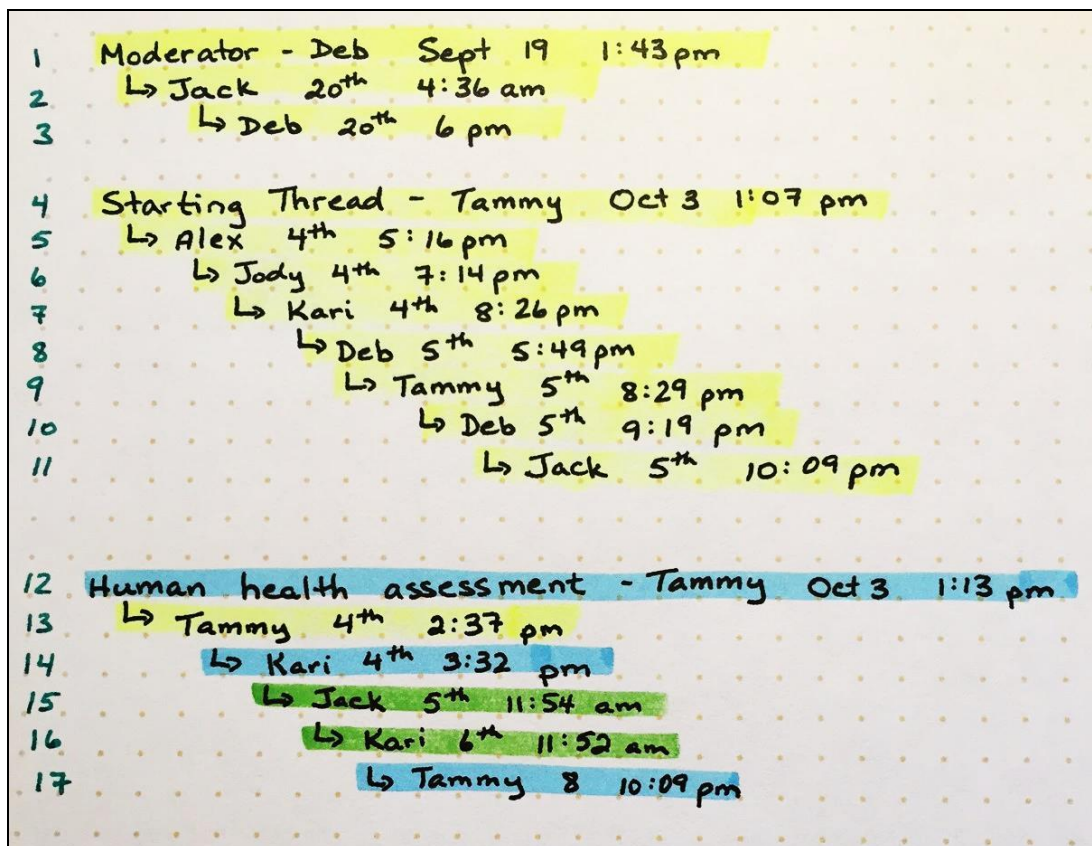


Figure 6. Appearance of an online asynchronous meeting in a discussion forum (yellow coded posts #1-11).

Although the blended teams did not have online meetings in the same way, the discussion forum sometimes contained evidence that such meetings occurred, but in a face-to-face format. For example, posts contained text such as "Don't forget we are meeting Wednesday at noon", or "Here are the notes from Thursday's meeting". For some teams, there was no explicit evidence on the forum of meetings occurring at all. Interviews did confirm that as expected, blended teams did meet face-to-face to brainstorm approaches and divide up the work, even if evidence of this meeting didn't explicitly occur on the discussion forum. Distance teams also made use of Skype, MSN messenger, telephone or other synchronous technologies to facilitate faster discussions, especially once teams had divided work into smaller segments that

were pursued by subgroups. This was confirmed both by interviews, and by the exchange of Skype or telephone information on the discussion forum.

***Organic discussions versus use of organizational scaffolds.***

As a result of the creation and use of the organization category for coding purposes, it was noticed that there were two contrasting discussion styles used by teams: the "organic" development of the discussion and the use of organizational scaffolds that provided structure to the discussion (See Figures 7 and 8 for some representative pseudo-examples). In an organic discussion, students started threads on an "as needed" basis, and it was not uncommon for a thread to contain only a single post, especially in blended team discussions. Figure 7 was a typical example of the organic posting structure when used by the blended cohorts. Notice that all the threads in this example were short and contained only one or two posts. It appeared as if each individual just started a new thread each time they posted, and the forum contained little in the way of discussion between team members. In spite of the lack of evidence on the online forums, interviews confirmed that discussion of the ideas was occurring face-to-face for blended teams (see Interviews). For distance teams that used the organic format, the threads were still started by various individuals on an "as needed" basis, although the forums did contain longer threads and discussion of ideas with other class members.

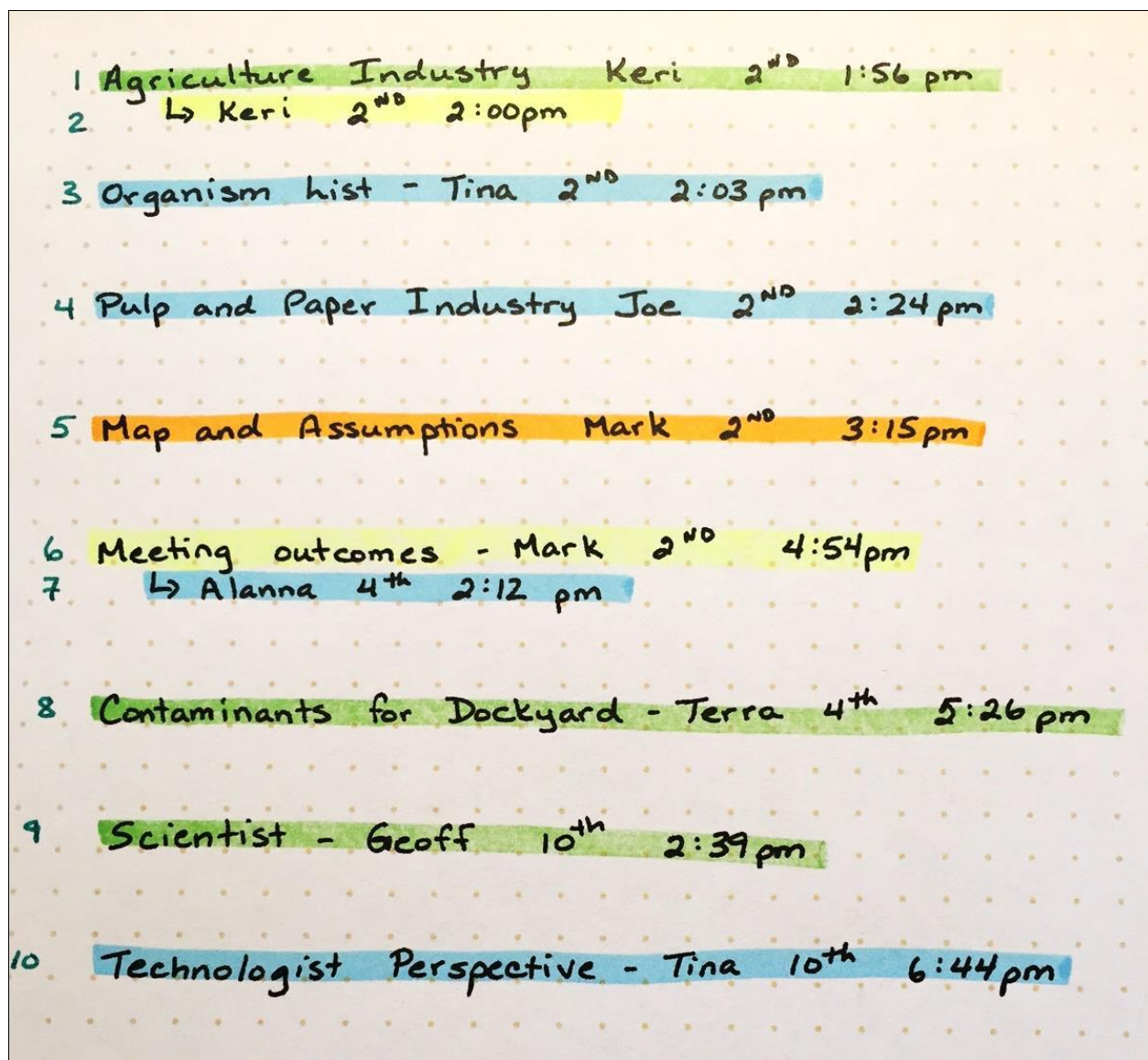


Figure 7. Organic thread organization of an online discussion from a blended team (indented entries indicate replies to the main thread).

Figure 8 shows a pseudo-example of a discussion forum that used the hard scaffolds provided in the PBL case problem as organizational scaffolds. Although each PBL case problem contained certain elements that had to be addressed in the final report (hard scaffolds), the number of these hard scaffolds decreased as students progressed from case problem one to four. When teams used organizational scaffolds, one member of the group (usually the student moderator) made a series of posts to the forum that contained the text of the hard scaffolds before the rest of the team

started posting. These posts did not usually contain any text other than that included in the hard scaffold, and just organized the discussion posts into discreet units. These organizational scaffolds were easily identified in the thread diagram as several organization posts (yellow coding) would be posted by one individual, often within a five minute time span at the beginning of the team discussion. These organizational scaffolds acted as headings to gather posts that contained information on a particular topic into discreet threads. An anonymized example of this behaviour can be observed in Figure 8, where Peter (pseudonym) posted three organization posts (yellow coded posts 1, 5, and 11) over a two minute span that provided structure to the team discussion. Notice that in this situation, all the posts from other individuals were replies to these organizational scaffolds—that is, other individuals did not start new threads. Post 16 was a first draft of the final report (Resolution post, orange coding), and this new thread was also started by Peter - the replies were edits and additions to the document by the rest of the team.

1	Case Study Question 1	Peter	Apr 17	2:55 pm	OL
2	↳ Hori	20 <sup>th</sup>	9:09 pm		A* 4 pg
3	↳ Lynn	21 <sup>st</sup>	10:19 pm		8L A* 2 pg
4	↳ Bob	29 <sup>th</sup>	9:50 pm		16L
5	Case Study Question 2	Peter	Apr 17	2:56 pm	OL
6	↳ Mark	19 <sup>th</sup>	8:12 am		2L A* 1 pg
7	↳ Peter	21 <sup>st</sup>	9:07 pm		8L
8	↳ Jen	22 <sup>nd</sup>	2:55 pm		4L A* 2 pg
9	↳ Mark	22 <sup>nd</sup>	7:15 pm		2L A* 1 pg
10	↳ Jen	26 <sup>th</sup>	3:23 pm		10L A* 4 pg
11	Case Study Question 3	Peter	Apr 17	2:57 pm	OL
12	↳ Peter	23 <sup>rd</sup>	9:01 pm		10L
13	↳ Bob	24 <sup>th</sup>	9:09 pm		12L
14	↳ Jen	24 <sup>th</sup>	10:15 pm		24L
15	↳ Peter	24 <sup>th</sup>	11:35 pm		2L A* 3 pg
16	What is needed to finish Case Study 4	Peter	Apr 30	4:28 pm	5L A* 55 pg
17	↳ Jen	5 <sup>th</sup>	12:15 pm		A* 55 pg
18	↳ Bob	5 <sup>th</sup>	4:24 pm		A* 56 pg
19	↳ Mark	6 <sup>th</sup>	7:30 am		A* 56 pg
20	↳ Lynn	6 <sup>th</sup>	9:35 am		A* 57 pg
21	↳ Peter	6 <sup>th</sup>	10:12 pm		A* 58 pg

Figure 8. Organizational scaffold thread organization of an online discussion from a blended team (indented entries indicate replies to the main thread).

Although both the distance and blended teams used organic and organizational scaffold approaches, the relative ratios of their use did vary. The blended teams were more evenly split between the two approaches (46% organizational scaffolds, 54% organic) than the distance teams (65% organizational scaffolds, 35% organic). Interestingly, most teams chose one approach or the other, and used it consistently across all four case problems. In situations where teams changed their discussion approach, there didn't seem to be any pattern to the change - some teams started by using organizational scaffolds for early case problems and moved to an organic format for later case problems; other teams started with an organic format and moved to the use of organizational scaffolds; and still other teams alternated between both approaches. Which approach was to be applied did not appear to be discussed on the

forum, but rather was an individual decision of either the student moderator, or a dominant personality in the group. During the interviews, one interviewee indicated that for his group, one of the members was really good at organizational things and the team just let her set up the discussion forum using organizational scaffolds, regardless of who the student moderator was.

A comparison of the distance and blended teams' counts of posts that included hard scaffolds showed that the distance teams used a mean of 6.17 posts including hard scaffolds per case compared to a mean of 3.05 posts including hard scaffolds per case for the blended teams, with standard deviations of 4.419 and 4.273, respectively. The Levene test for the equality of variances demonstrated that the variances are equal ( $F = 0.063$ ,  $p = 0.802$ ). An independent samples  $t$ -test ( $t(134) = -4.170$ ,  $p < 0.001$ ) indicated that the mean number of posts that included hard scaffolds per case was significantly higher for the distance teams than for the blended teams. The Cohen's  $d$  for this difference was moderate at 0.73 standard deviations.

### ***Building on their own ideas.***

Figure 9 shows a pseudo-example of a thread in which a student used the discussion forum as a note taking area. Kelly (pseudonym) started a thread with an exploration post (blue coding). Each of her subsequent exploration posts was paraphrased from a different single source (posts 64-68), and the thread culminated in an integration post (post 69) that combined the information from all the sources cited in the thread. None of the individuals who were available to be interviewed exhibited this behaviour in their posting, so it was not possible to follow up on the reasons for it.

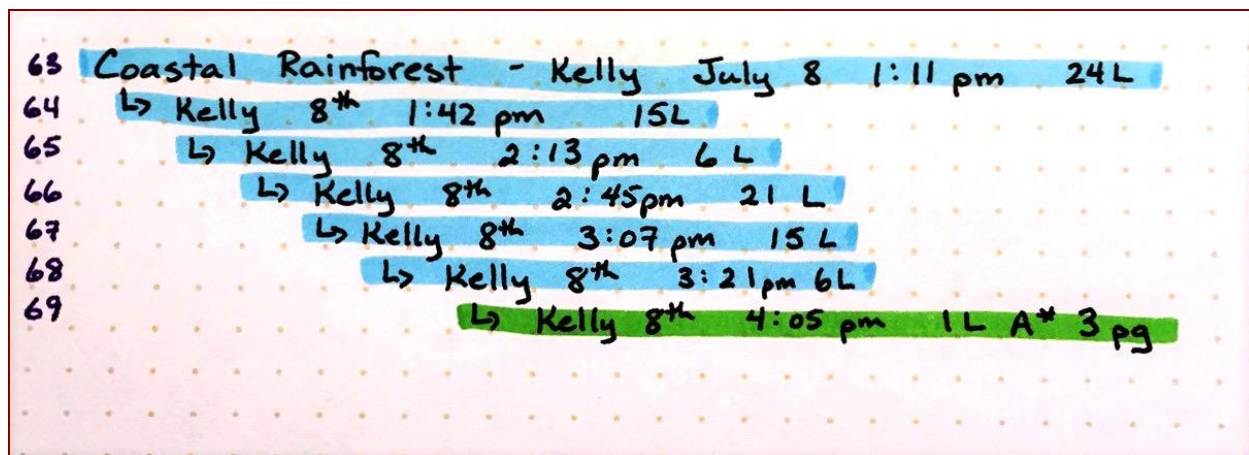


Figure 9. Pseudo-example of a thread where a student builds their own ideas and research (explore posts, blue coding) into an integration post (green coding) that incorporates the ideas.

#### ***Undocumented resolution.***

Although in an ideal world, it would have been nice if the online discussions contained all the communication that occurred between team members, the reality is that even for distance teams who use the discussion forums as a primary means of communication, there were interactions that happened offline. Both blended and distance groups showed evidence that “undocumented resolution” occurred. Some examples of such behaviour included: questions that were asked but not answered on the forum; information that was not posted to the forum but was included in the final report; and documents that were not assembled on the forum but were handed in.

#### ***Methods of document assembly.***

The design for the Ecotoxicology course included a requirement for a team report that summarized the discussion and solution of each of the four cumulative PBL case problems. This requirement seemed to have resulted in many posts that were ready to be integrated into a draft of the report. That is, they were written in complete sentences with appropriately styled paragraphs and citations, rather than in a more casual writing style. Teams assembled their final reports either on the forum (usually distance teams) or offline (usually blended teams), using one of three observed methods: end point assembly, sectional assembly or template-based assembly.

End point assembly was considered to have occurred when document assembly occurred entirely at the end of the posting process. Teams that used this method established an internal deadline for the addition of information to the forum, and then the student moderators for that case problem assembled a draft report that they circulated to the rest of the team for comments and corrections. If the draft appeared on the forum, it was usually observed two to three days before the report was due to the investigator. No observable assembly occurred prior to this point, although individuals may have integrated information from several sources into their posts. There was no observed relationship between the use of this type of assembly and whether organic or organizational scaffolds were used as their group approach to the discussion forum.

Sectional assembly was observed in some teams that used the organizational scaffold approach for the discussion forum. In these teams, several individuals contributed information as replies to the organizational scaffold post, and these posts were summarized, by either the moderator or one of the individuals assigned to that thread, into a format suitable for inclusion in the final report. These summaries were either posted as a final integration post to that same thread, or to a new thread created specifically for these summaries - often named "Drafts for the final report" or something similar. The moderator then assembled these summaries into the final report, which was circulated for comments and corrections. Sectional assembly was explicitly observed on the discussion forum when it occurred.

In template-based assembly, a template was generated for either a section of the final document, or the final document as a whole. It was used by everyone and was most commonly observed for information that the team agreed was to be presented in tables. This type of document assembly results in a series of integration posts occurring earlier in the discussion than would be expected in a thread for sectional assembly. Figure 10 below shows a pseudo-example of a thread that included the use of template-based assembly. The yellow coded organization posts (33-37) represented the generation of the base template. This example shows a collaborative effort between five students as they generated the template and agreed to use this approach. Once the template was agreed upon and its use had begun, there was a lot of integration of ideas as it passed back and forth between students (green coded posts). When the template

was completed to the team's satisfaction, it was either integrated into the draft report or became the draft report, depending on the extent of the template.

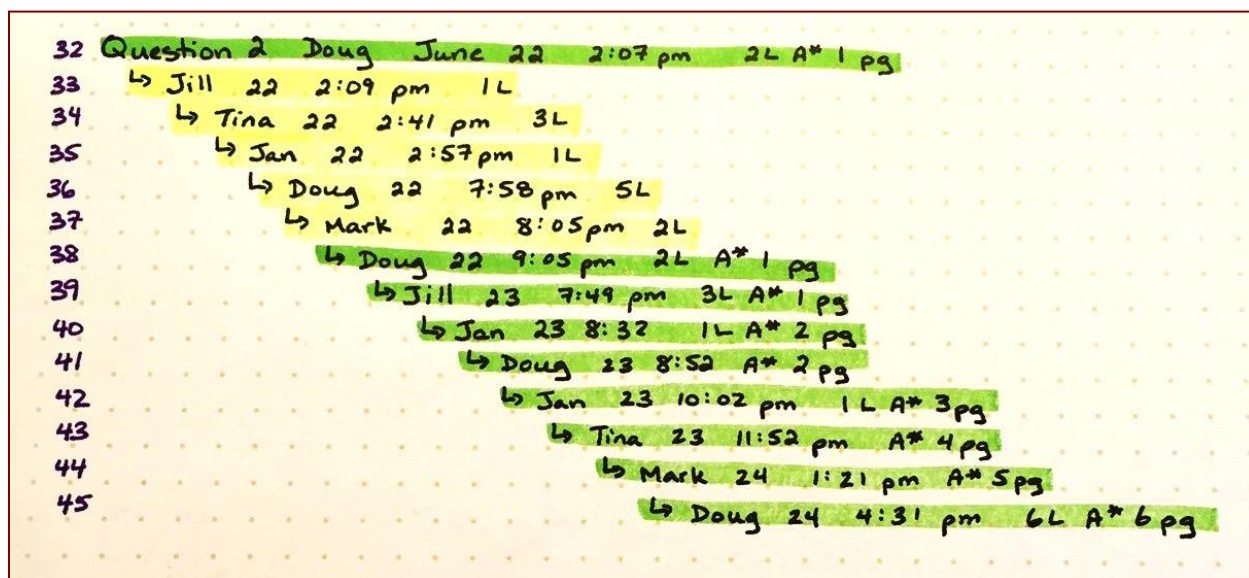


Figure 10. Pseudo-example of the use of a template-based assembly to integrate ideas (integration, green coded posts).

### ***On versus off-forum document assembly.***

As noted above, PBL activity in the Ecotoxicology course required submission of a team report for each of the four case problems. The report summarized the discussion and addressed various aspects of the problem. All the teams in both programs handed in the necessary four case problem reports, but the teams differed by program with respect to whether the report documents were assembled on or off of the discussion forum. For the distance teams, 91.7% (55/60 case reports) were assembled directly on the discussion forum. Of the remaining five case reports, 4/5 had notations on the discussion forum that indicated the case problem report was assembled on Google Docs or a similar collaborative writing platform. As the distance teams don't have the same opportunity to meet face-to-face to accomplish tasks such as document assembly and editing, it is reasonable to expect that as time goes on, the use of collaborative online writing tools will occur more frequently, as students become more familiar with them. In contrast, as one might expect for the blended teams, few case reports (18.4% or 14/76 case reports) were assembled directly on the discussion forum. Interviews

indicated that document assembly was done face-to-face, often with a group assembled around a single computer.

*Impact of collaborative writing tools.*

When the online discussion forums were first used for the Ecotoxicology course, the documents were either assembled on the discussion forum (distance teams), or they were assembled by students working face-to-face (blended teams). Since 2006, reference to the use of collaborative writing tools such as Google Docs, has been occasionally observed in the discussion forums. Although the use of such tools has not heavily impacted this study, with only two teams (a 2006 distance team that used a collaborative writing tool (Writerly) for 2 case problems and a 2010 distance team that used Google Docs for 3 case problems) electing to use these tools, future studies of online discussion forums will need to take their use into account. When they were used, collaborative writing tools were observed to have changed the online approach/behaviour of the team in the discussion forum.

Team members were still required to post to the discussion forum, and were cautioned that without instructor access, it would not be possible for the instructor to help the team correct misconceptions in the online environment prior to the final report being graded. Although some student moderators provided a link that invited the instructor to observe their collaborative off-forum writing, this was not always done, and sometimes caused issues in terms of completeness. In one example the instructor was not provided access to the Google Doc, and then a major error of omission was discovered when the final report was marked. This situation made most of the team rather skittish about using Google Docs, and the team abandoned its use for the next case problem. Another difficulty observed for some students within teams was the learning curve associated with Google Docs, but the support of team members who were more familiar with the program seemed to overcome this issue.

Teams that used Google Docs or similar collaborative writing tools posted more organization posts, and fewer posts with critical thinking indicators (exploration, integration or resolution posts) per case problem than teams that used the discussion forums as their primary communication tool because the evidence of this activity

occurred directly on the Google Doc. In Figure 11, the yellow coded organization posts in the first two threads were all directional pointers to the Google Doc that the team was using (e.g. "I have just posted the justification for choosing our contaminants to the Google Doc").

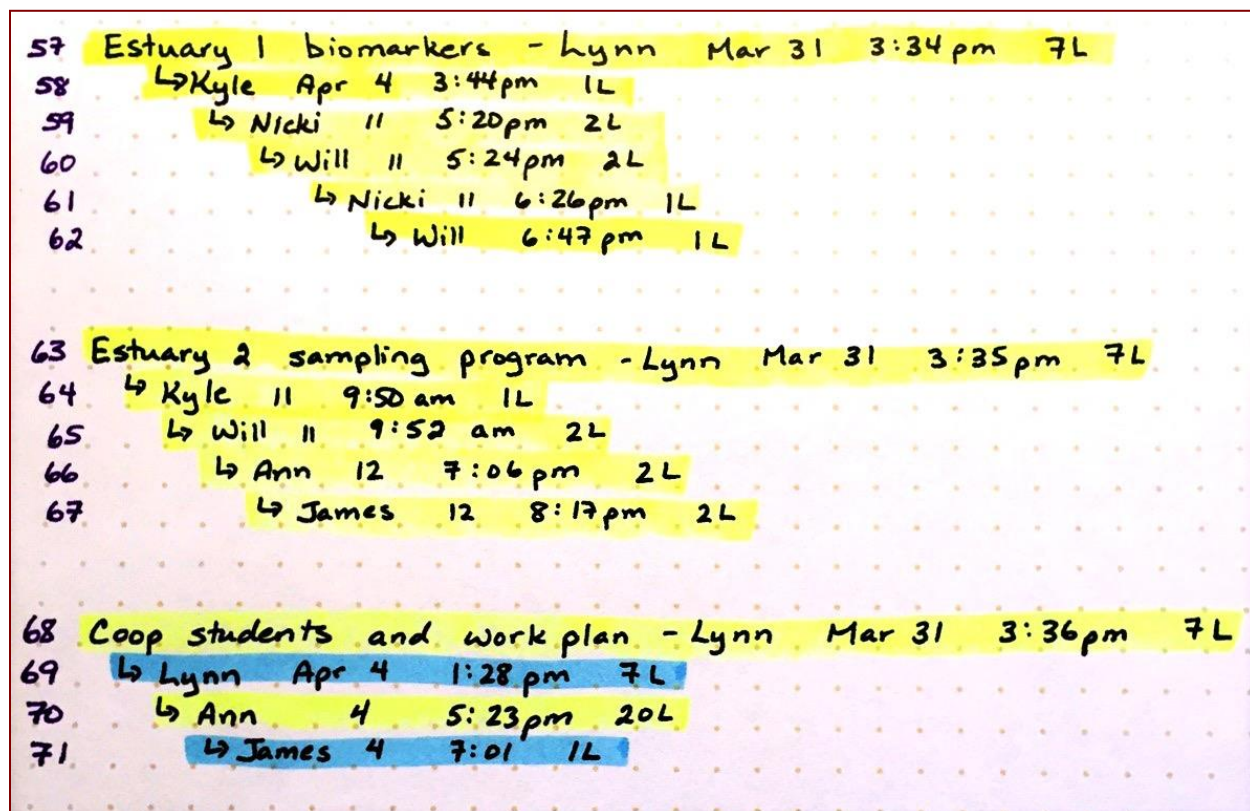


Figure 11. Example of the effect of Google Docs (all the yellow coded organization posts point to the Google Doc).

### **Document assembly - use of sign-outs.**

When a document was being assembled on the discussion forum, identifying which version of the document was the most current could be problematic, especially if several members of the group were involved in editing. While the use of Google Docs or similar collaborative tools that were able to integrate changes made by more than one author simultaneously was one possible solution for this problem, another was the use of document sign-out procedures. Figure 12 shows a pseudo-example of a document assembly thread in which a sign-out procedure was used. Notice the yellow coded organization posts that were followed by integration (green) or resolution (orange) posts

by the same author. The organization post marked the student signing-out the document, and approximately what time they expected to re-post the updated document. The subsequent student's integration or resolution post contained the modified version of the document for further editing or comments. These posts often included text that detailed the changes they had made to the document, and sometimes also pointed out what work still needed to be done. The use of such a sign-out system seemed to prevent confusion about which version of the document was the most current. This was useful, as not all teams identified version numbers on their documents.

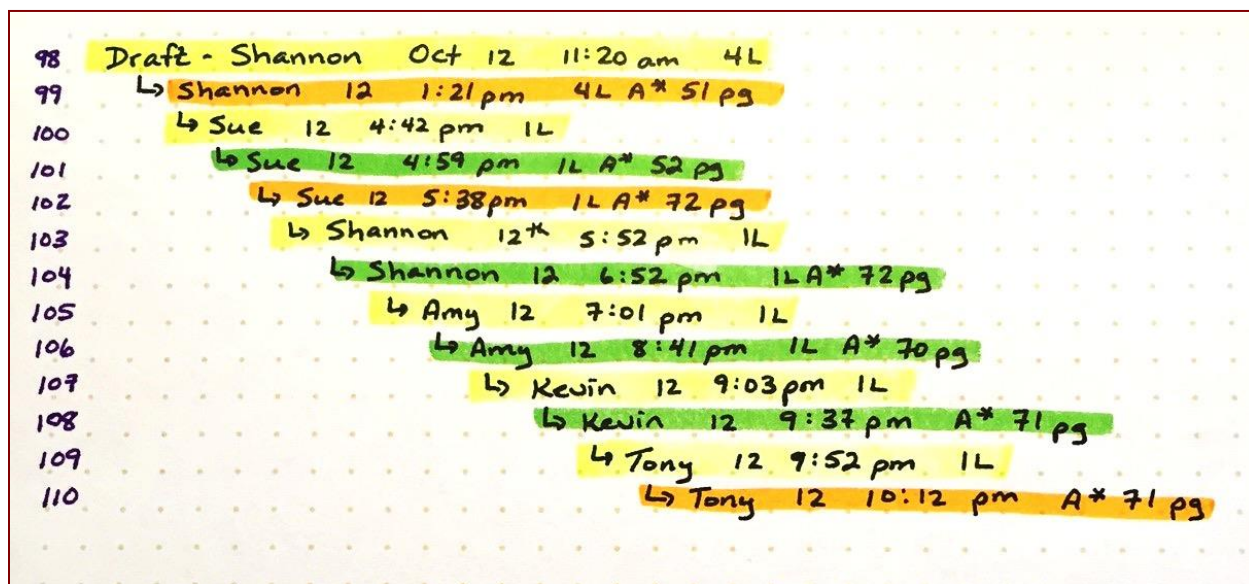


Figure 12. Example of a document assembly thread making use of a sign-out procedure (yellow-coded organization posts followed by green-coded integration or orange-coded resolution posts by the same author).

### Content analysis.

Although the Cofl cognitive indicators were useful for looking at the research questions that focused specifically on critical thinking, other elements of the discussion forum activity were not captured by these indicators. These were sometimes relevant to determining how the teams were approaching the PBL exercise, as well as what scaffolds students were using to support their learning. As noted previously, the initial step of the content analysis was to read through all the discussion posts. Some general

impressions arose from this read-through. Both distance and blended student posts provided evidence suggesting that students were working together, used various types of materials to support their learning, and interacted socially in the discussion forums. Evidence of collaboration, learning scaffold use and social interactions all seemed to occur more frequently in the distance team discussions than in the blended team discussions.

Investigation of these impressions required the development of coding schemes separate from the Cofl model for collaborative behaviours and the learning scaffolds students used, because the Cofl model didn't include indicators to characterize these behaviours. Team social interactions were categorized using the social presence indicators from the Cofl model as described by Garrison et al., (2001) because they were already part of the Cofl model and had been validated (Arbaugh, 2007).

The online discussion posts were analyzed for their content, focusing on evidence of students working together (collaboration), supports for their learning (learning scaffolds), and social interactions. The following sections describe development of the two secondary coding schemes for collaboration and learning scaffolds, as well as the application of the Cofl social indicators coding scheme to the online discussion posts.

### ***Collaboration and learning scaffolds (CLS) coding schemes.***

This section describes the development of the indicators and behavioural examples for the CLS coding schemes. The two pilot tests that were run as the CLS coding schemes were being finalized are described. The next section includes a final list of collaboration indicators (see Table 21) as well as a summary comparison of their relative use by distance and blended teams. The section on learning scaffolds includes the final list LS indicators (see Table 23), a summary comparison of their relative use by distance and blended teams, and a comparison of NVivo and manual frequency counts for LS use by 2004 distance and blended teams. This is followed by a summary comparison of the use of Cofl social presence indicators by distance and blended teams, and some results from mixing Cofl and CLS indicators.

An open coding approach was used to look for evidence of collaboration between students, as well as evidence of the kinds of learning scaffolds being used. Initial evidence of collaborative work included indicators like sharing references, and directional sign posts for items that were posted to collaborative workspaces, but also included items like MSN logs and exchanging off-forum contact information (e.g. telephone numbers, Skype or MSN ids). Initially, evidence of learning scaffolds included the citation of source materials (websites, textbooks, etc.), as well as just-in-time teaching presence, and answers to questions directed to the instructor.

The first pilot test used a single discussion forum for a single team (Team 1, Case 1 from the blended 2006 cohort). This first pilot test attempted to integrate the use of the Cofl cognitive presence indicators with the Cofl social presence indicators and the newly-generated CLS indicators. The first pilot test highlighted a problem. While a single post could be easily assigned to one of the mutually exclusive Cofl cognitive categories (see Procedure section of Methods), resulting in a reasonably sized data set that could be compared to other studies (e.g. Garrison et al., 2001; Meyer, 2003), the categories for the CLS and Cofl social presence indicators could not capture a post in a single category. That is, a single post could contain multiple different examples of collaborative behaviour indicators, learning scaffolds or social interactions, in the form of words, sentence fragments or sentences. In addition, the indicators within the collaboration or learning scaffolds coding schemes were not mutually exclusive. For example, a textbook citation and a citation to a website found by students are both examples of indicators in the LS coding scheme. It is possible for a single post to have contained a textbook citation, as well as two other citations to websites that the student found. The post having been coded to the textbook citation didn't preclude the post also being coded for the website citations. Therefore, simply enumerating the number of posts that contained at least one indicator of collaboration, or learning scaffold was not sufficient to address the research questions; and trying to code simultaneously for the Cofl cognitive presence and CLS indicators was too difficult to accomplish or interpret.

The second pilot test using the same single discussion forum as the first pilot test demonstrated that treating the coding of the posts with the Cofl cognitive presence indicators separately from the coding of the CLS and Cofl social presence was a more

successful approach. It was also much more straightforward to interpret. As a result of this second pilot test, smaller units of analysis (i.e. words, sentence fragments and sentences) were used for the CLS and Cofsocial coding schemes, while the post remained the unit of analysis for the Cofl cognitive coding scheme. The sections below describe the CLS indicators and the behavioural evidence underlying them, as well as a summary of their relative use by distance and blended teams in the online PBL case problem discussions.

*Collaboration indicators.*

As a result of the pilot coding tests, it was also decided to treat the CLS and Cofsocial indicators as a second coding system that was independent of the Cofl cognitive indicators, in order to address research questions one, two and six. Table 23 contains the list of collaboration indicators as well as the behavioural examples for each indicator. These indicators were applied to the discussion forums for all teams.

Table 23 *Collaboration Indicators Observed in Discussion Forums for Online PBL Activity for Distance and Blended Teams*

Indicator	Behavioural example
Answering questions	Answers content-related questions asked by team members (e.g. "Can someone explain the chemistry of smog?").
Asking questions	Asks questions of others, including the investigator.
Availability and timeline to meet group expectations	<p>Informs team about personal availability (e.g. "I'm travelling until Wednesday").</p> <p>Informs team about when they will post (e.g. "I'm still working on my section about sentinel species but I'll post what I have tomorrow morning").</p>
Directional	<p>Points reader to a specific location such as a thread, wiki, GoogleDoc, or ftp server location. (e.g. "See the final drafts thread for my information." or "I posted the list to the Google Doc.").</p>
Document assembly	<p>Adds content to the report.</p> <p>Edits or suggests changes to the report.</p> <p>Informs team that the report was submitted to the investigator.</p> <p>Signs out the document to work on it.</p> <p>Presents an initial draft of the report.</p>

Informing the team	Informs the team about what you are going to do or have done (e.g. "I added my section onto Tim's." or "I'm planning to look up Henry's constants this afternoon.")
Meeting notes	Posts minutes of face-to-face/Skype/MSN or telephone meetings (e.g. "Here are the minutes from today's meeting...").
Meeting organizers	Sets a date and time for meetings (e.g. "Don't forget we are meeting at the library tomorrow at noon" or "We are meeting via Skype at 2pm Pacific time"). Exchanges of contact information and availability for contact. Requests a meeting (face-to-face or via telephone, Skype, MSN or Facebook as appropriate).
Moderator	Suggests an approach or action plan. Requests for Information (e.g. "Could someone please look into this topic?"). Encourages discussion. Posts templates or outlines for the team to use. Provides feedback post-case on the discussion or final report (e.g. "This is what I think we could do better next time...").
Multi-author messages	Messages explicitly identified by the poster as being the work of more than one student (e.g. "This is the table that Diane and I worked on together").

Request for direction/feedback	Asks for advice on what topic to research. Asks who needs help. Requests feedback on their work (e.g. “What does everyone think of this?”).
Sharing references	Suggests references for other students to use (may or may not be directly attached to the post) (e.g. “Here is a link to this great website...”).
Sign-ups and plan agreement	Volunteers to take on tasks. Agrees or disagrees with the suggested approach or plan.
Use of templates	Uses templates provided by other students (e.g., A student moderator may have posted a blank table that the other members of the group were to add their information into before posting the table back to the discussion group. Posts that included the completed table were coded as having contained a use of template indicator).

A series of bivariate Pearson correlations were run to determine if the collaborative indicators varied with one another (see Table B9 in Appendix B). As all the indicators were based on behaviours selected as examples of students working together, it was expected that correlations existed between the various pairs of indicators. This proved to be the case and significant strong or moderate correlations ( $p < 0.05$ ) were observed between most pairings. Two exceptions were identified: the meeting notes and multi-author messages indicators, which did not significantly correlate with most other indicators or with each other. The meeting notes and multi-author

messages indicators were the two least observed indicators, and each was found to be significantly correlated with the meeting organizers indicator(see Table B9).

Distance teams had more posts containing each of the collaborative indicators with the exception of multi-authored messages. A series of independent samples *t*-tests were used to compare the distance and blended teams' mean counts of the number of posts per case problem that included each collaborative indicator. The variances of indicators between the distance and blended groups were only equal for the meeting notes, multi-author messages, and use of templates (see Table 24). The *t*-tests indicated that the mean number of posts per case that included each collaborative indicator was significantly higher for the distance teams than the blended teams ( $p < 0.05$ ), with the exception of the meeting notes and multi-author messages indicators (see Tables 24 and B10).

Table 24 *Descriptive Statistics for Collaboration Behaviours Scores for Distance and Blended BSc Students in an Online Problem-Based Learning Activity during an Ecotoxicology Course*

	Program	N	Mean	Std. Deviation
Answer questions	Distance	60	10.42*	6.94
	Blended	76	0.09	0.40
Ask questions	Distance	60	19.68*	12.27
	Blended	76	0.47	1.25
Availability/timeline	Distance	60	14.72*	6.36
	Blended	76	0.66	0.87
Directional	Distance	60	2.48*	2.80
	Blended	76	0.44	0.84
Document assembly	Distance	60	21.48*	10.82
	Blended	76	1.03	2.01
Informing the team	Distance	60	17.12*	8.18
	Blended	76	1.16	2.28

Meeting notes	Distance	60	0.47	1.51
	Blended	76	0.43	1.01
Meeting organizers	Distance	60	1.50*	2.10
	Blended	76	0.70	1.03
Moderator	Distance	60	20.38*	12.72
	Blended	76	3.03	3.79
Multi-author messages	Distance	60	0.52	0.98
	Blended	76	0.64	0.96
Request direction/feedback	Distance	60	2.98*	3.10
	Blended	76	0.53	1.05
Share references	Distance	60	3.27*	3.47
	Blended	76	1.14	1.91
Topic signup/plan agreement	Distance	60	13.93*	6.85
	Blended	76	0.64	1.48
Use templates	Distance	60	5.92*	6.76
	Blended	76	2.55	8.19

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\* Independent samples *t*-test are significantly different at the  $p < 0.05$  level.

#### *Learning scaffold (LS) indicators.*

The learning scaffold (LS) indicators were treated as an additional coding system that was independent of the Cognitive indicators. The LS indicators were used to examine research questions four and six, which addressed how students were supporting their learning. Table 25 contains the list of LS indicators and behavioural evidence for each one that was applied to the discussion forums for all teams.

Table 25LS *Indicators in Discussion Forums for Online PBL Activity for Distance and Blended Teams during an Ecotoxicology Course*

Indicator	Behavioural example
Action plan	Posts an action plan or approach for the team to follow.
Hard scaffolds from the case	Posts material quoted directly from the case to organize the post or the discussion.
Instructor post	Corrects student misperceptions. Answers questions directed to instructor. Addresses class-wide problems.
Reference to lecture notes	Cites lecture notes as source material.
Reference to textbook	Cites textbook as source material.
Reference to website from case or course outline	Cites a website that was recommended in the specific case or the course outline.
References to websites found by students	Cites source material found by students as source material.
References to work experience	Cites personal work experience as source material.
Reposting instructor information	Posts information provided by the instructor from a previous post, email or face-to-face meeting (e.g. "I emailed the investigator and she said...").
Sign-up sheets	Provides a list of topics for students to sign up for (e.g. "Everyone please sign up for one of the topics on the list below before Saturday").
Templates	Provides templates for the team to follow for either the entire document or part of the document (e.g. "Here is a table for everyone to fill on for their contaminants of concern...").

The LS indicators seemed to split into two groups – learning scaffolds that are related to instructor and group organization, and learning scaffolds that had to do with

citations (source materials). The learning scaffolds related to instructor and group organization were analyzed separately from the citations learning scaffolds.

Instructor and group organization LS scaffolds.

Distance teams had more posts per case for all investigator and group organization LS indicators (see Table 26). A series of independent samples *t*-tests were used to compare the distance and blended teams' mean counts of the number of posts per case problem that included each of the instructor and group organization LS indicators. The variances of the distance and blended groups were only equal for the template indicator (see Table 26). The *t*-tests ( $p < 0.05$ ) indicated that the mean number of posts per case that included each of the instructor and group organization LS indicators was significantly higher for the distance teams than the blended teams, with the exception of the templates and reposting instructor information indicators (see Table 26, Table B11 in Appendix B).

Table 26 *Descriptive Statistics for Instructor and Group Organization LS Observed In Use by Distance and Blended BSc Teams in an Online Problem-Based Learning Activity during an Ecotoxicology Course*

Indicator	Program	N	Mean	Std. Deviation
Instructor posts	Distance	60	4.65*	3.57
	Blended	76	0.17	0.50
Action plans	Distance	60	3.00*	2.68
	Blended	76	0.62	0.90
Templates	Distance	60	1.38	1.54
	Blended	76	0.95	1.53
Reposting instructor info	Distance	60	0.70	1.33
	Blended	76	0.34	0.97
Sign-up sheets	Distance	60	0.43*	0.89
	Blended	76	0.03	0.16

\* Independent samples *t*-test are significantly different at the  $p < 0.05$  level.

Figure 13 shows a summary comparison of the instructor and group organization LS from Table 26 that supported learning and group work by blended and distance students. The distance students posted more examples of all these learning scaffolds than the blended students, although the independent *t*-tests described above demonstrated that the observed differences in the use of templates and the reposting of instructor information were not significant.

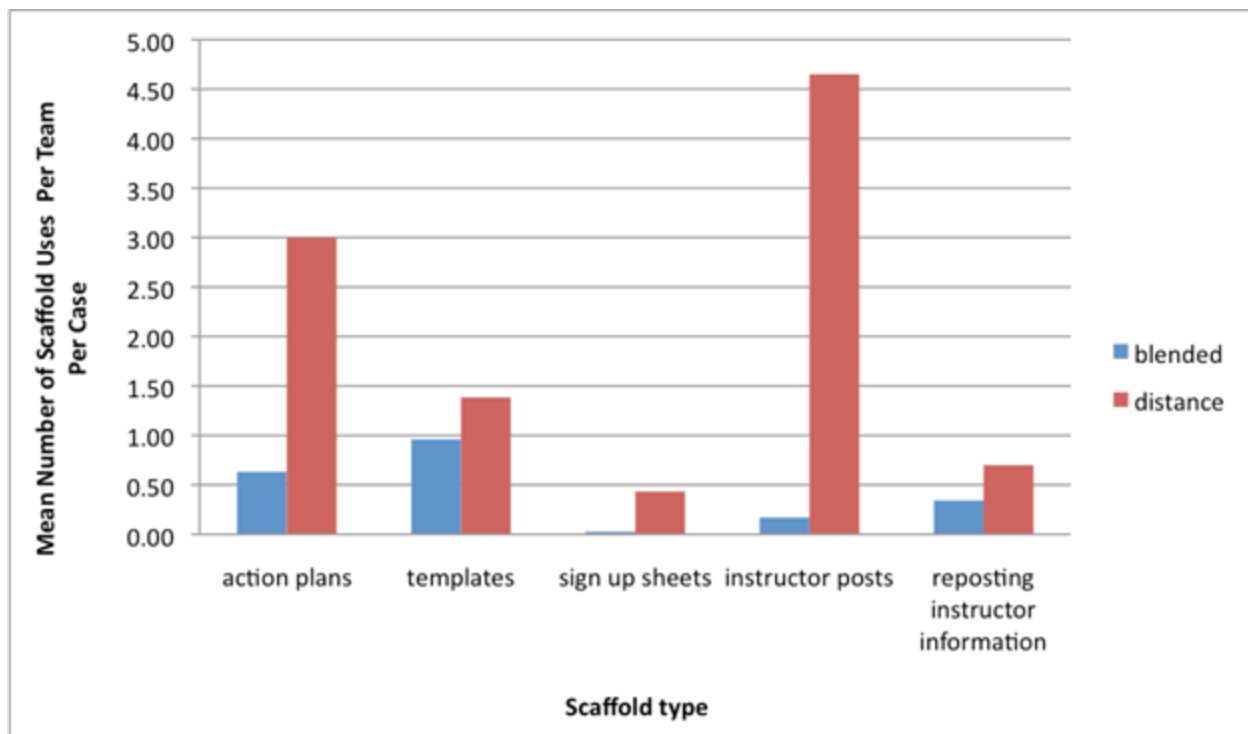


Figure 13. Investigator and group organization LS observed in use by distance and blended BSc teams in an online PBL activity during an Ecotoxicology course.

Citations learning scaffolds.

A read through of the discussion forums gave the impression that students were drawing on a number of different source materials for their posts: websites that they found themselves, textbooks, lecture notes, websites recommended by the course or case, as well as personal work experience. Distance teams posted more messages per case with references to textbooks, websites from the course or case, and work experience (see Table 27). Independent samples *t*-test comparisons were done of the distance and blended teams' mean counts of the number of posts per case problem that included each of the citationsLS indicators. The variances of the distance and blended teams were equal for the references to lecture notes and references to textbooks indicators. The *t*-tests indicated that the mean number of posts per case that included each of the citationsLS indicators was only significantly different ( $p < 0.05$ ) for the reference to lecture notes and reference to work experience LS indicators (see Tables 27 and B12 in Appendix B).

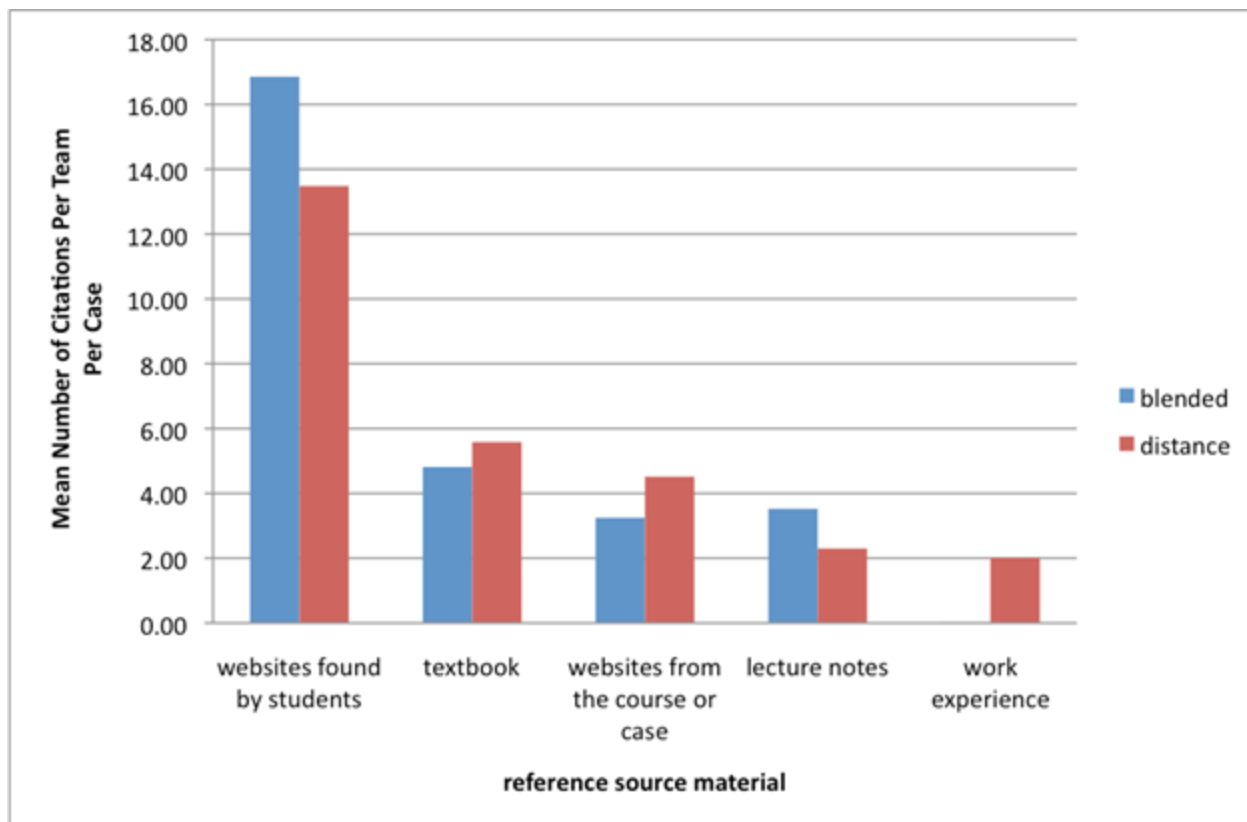
Table 27 *Descriptive Statistics for the t-test Analysis of the Source Material Learning Scaffolds for Distance and Blended Students during an Online PBL Activity in an Ecotoxicology Course*

Indicator	Program	N	Mean	Std. Deviation
Websites found by students	Distance	60	13.48	10.54
	Blended	76	16.42	14.86
Textbook	Distance	60	5.58	5.51
	Blended	76	4.70	4.46
Websites from course	Distance	60	4.52	4.59
	Blended	76	3.21	3.49
Lecture notes	Distance	60	2.30*	3.50
	Blended	76	3.48	3.34
Work experience	Distance	60	2.02*	2.94
	Blended	76	0.01	0.11

\* Independent samples *t*-test are significantly different at the  $p < 0.05$  level.

*NVivo and manual coding of attachment citations.*

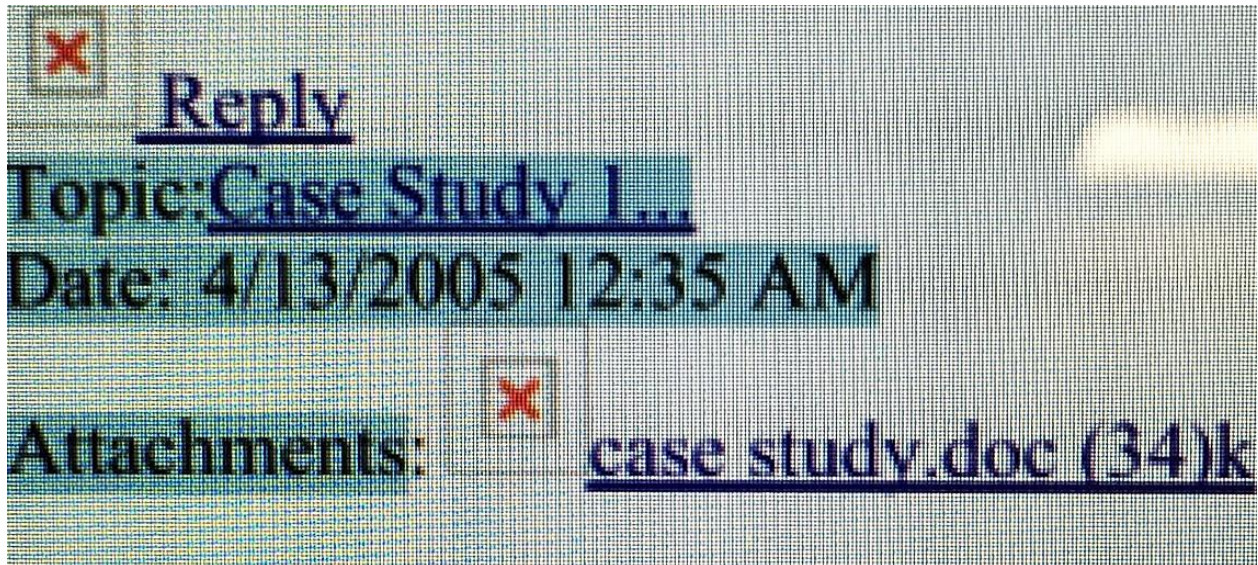
Figure 14 below summarizes the results of Table 27. Notice that Figure 14 indicated that blended teams used more websites found by students and more references to lecture notes than distance students, while distance students referred to work experience more often.



*Figure 14.* Citation LS observed in use by distance and blended BSc teams in an online PBL activity during an Ecotoxicology course.

One of the first impressions that arose from the read through of the discussion forums was that distance students used more citations for sources that they found themselves than blended students. As this impression was at odds with the results shown in Figure 14, which were based on the frequency counts generated by NVivo, a closer look at the reasons for this disconnect was warranted.

The screen shot of a single post shown in Figure 15 illustrates how the issue of NVivo counts not matching the investigator's impression of the data may have come about. The post contains an attachment, "case study.doc", and there is no text in the body of this post. When the post was coded, the attachment was opened, checked for any citations that were present and categorized. The name of the attachment was then highlighted and the codes were applied for each applicable category in NVivo. Case study.doc was coded as having a reference to websites found by students and a reference to a website from the course or case. The graph of learning scaffolds used per case by the teams shown in Figure 14 reflected these counts.



*Figure 15.* A screen shot of a post with an attachment in an online discussion forum.

When the case study.doc attachment shown in Figure 15 was opened, it had eight different citations to websites found by students and one from the course or case. The graph shown in Figure 16 was produced by recoding the citations by hand for the 2004 distance and 2004 blended cohorts only. Notice that this graph indicates that the distance students were citing more reference material that they located themselves than their blended counterparts - this is the opposite result from that shown in Figure 14.

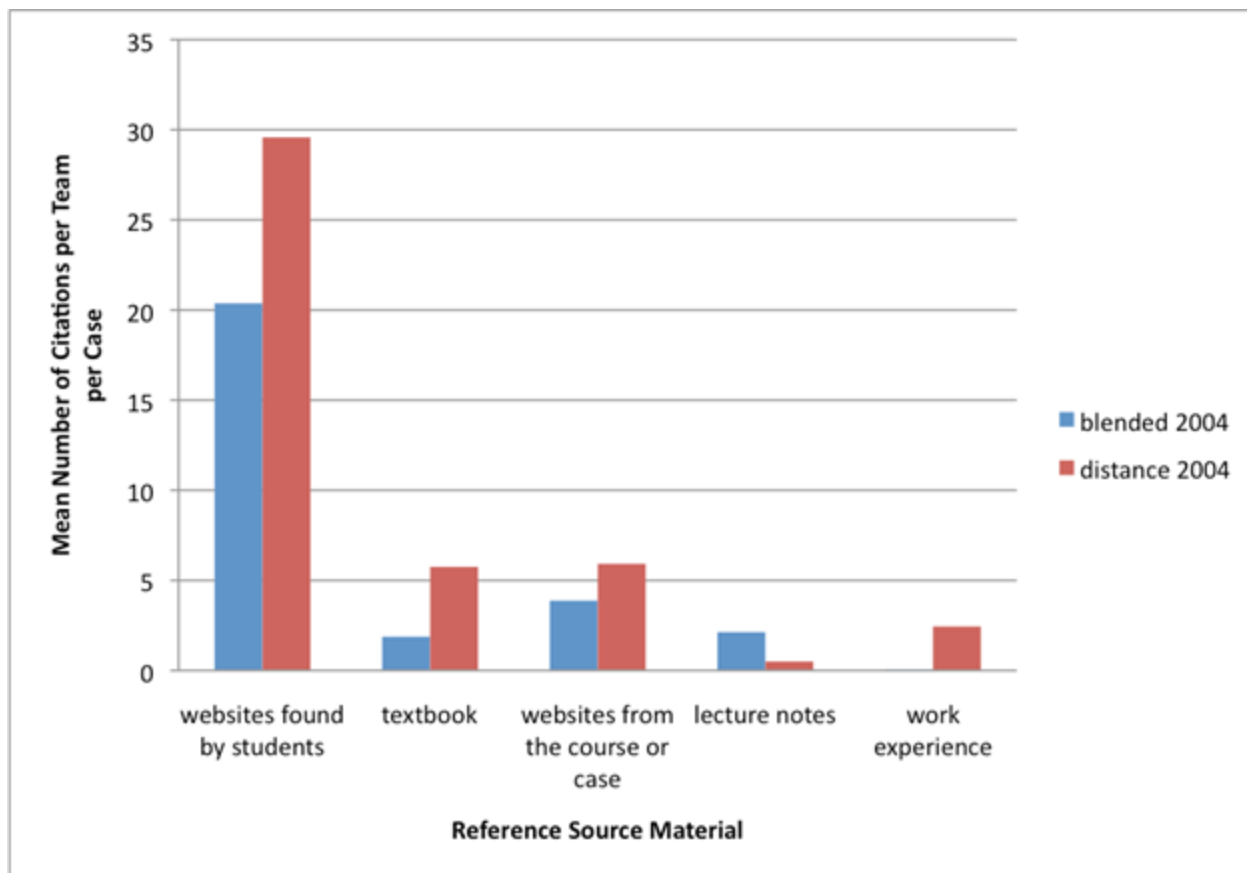


Figure 16. Citation LS observed in use by distance and blended BSc teams in an online PBL activity during an Ecotoxicology course (2004 cohorts - citations in attachments counted by hand).

The distance teams generally had more posts of each type than blended teams with the exception of references to lecture notes (see Figure 16, Table 28). A series of independent samples *t*-tests were used to compare the 2004 distance and blended teams' mean counts of the number of posts per case problem that included each of the citations LS indicators. The variances of the distance and blended groups were equal for the reference to websites found by students, references to websites from the course or case and reference to lecture notes indicators (see Table B13 in Appendix B). The *t*-tests indicated that the mean number of posts per case that included each of the citations LS indicators was significantly different ( $p < 0.05$ ) for the distance and blended teams for the reference to lecture notes and work experience indicators, and

approaching significance for the references to textbooks indicator (see Tables 28 and B13).

Table 28 *Descriptive Statistics for the Independent Samples t-test Analysis of the Citations LS for Distance 2004 and Blended 2004 Cohort Students During an Online PBL Activity in an Ecotoxicology Course*

	Program	N	Mean	Std. Deviation
Websites found by students	Distance	12	29.58	26.47
	Blended	16	20.38	18.87
Textbooks	Distance	12	5.75	6.05
	Blended	16	1.88	1.63
Websites from course or case	Distance	12	5.92	4.76
	Blended	16	3.88	4.21
Lecture notes	Distance	12	0.50*	0.80
	Blended	16	2.13	2.39
Work experience	Distance	12	1.83*	2.55
	Blended	16	0.06	0.25

\* Independent samples *t*-test are significantly different at the  $p < 0.05$  level.

The overall conclusions of the analysis were not changed compared to the analysis of the entire data set, although Figure 15 showed the 2004 distance teams cited more websites that they found themselves than the 2004 blended teams, which aligned with the investigator's initial impression of the data. The differences in the use of lecture notes and work experience were still significantly different between the distance and blended groups, and there were still no significant differences for citations of websites found by students; websites from course or case; or textbook use (although the difference for textbook citation was almost significant).

*Social indicators- Cofl model.*

Social interactions, such as addressing a post to a specific individual, seemed to be targeted to subgroups within a discussion team, and appeared to occur more frequently in the distance than the blended team discussion forums. In order to examine social interactions within the discussion forum teams, the social presence indicators from the community of inquiry model will be used.

Social presence in the Cofl model has three components or indicators: group cohesion, open communication, and affective expression (Garrison and Arbaugh, 2007). The cohesion indicators from the Cofl model were the most commonly used of the social indicators in both the distance and blended team discussion forums. The cohesion indicator included three behavioural examples: individuals being addressed or referred to by name; the group being referred to using inclusive pronouns (e.g. "Hey Team Green..."); or salutations or closures being used (Garrison and Anderson, 2003, p.51). Open communication indicators appeared to be used more frequently by distance than blended teams (see Table 29). Posts that included open communication indicators were as follows: they continued a thread; quoted from or referred explicitly to other's messages; asked questions of other students or the moderator; or complimented/agreed with others' ideas (Garrison and Anderson, 2003, p.51). The Cofl affective expression indicators were used more frequently by the distance teams than the blended teams (see Table 29). Posts that contained affective indicators were those in which students shared feelings, humor or personal experiences (self-disclosure) (Garrison and Anderson, 2003, p.51).

A series of bivariate Pearson correlations were run to determine if the presence of the social indicators varied with one another when the distance and blended teams were combined. There was a weak but significant correlation between the cohesion and open communication indicators ( $r(137) = 0.269, p < 0.001$ ) and a strong significant correlation between the cohesion and affective indicators ( $r(137) = 0.621, p < 0.001$ )

Instances of the use of Cofl social presence indicators per case in discussion posts were higher for distance teams than blended teams (see Table 29). A series of independent samples *t*-tests were used to compare the distance and blended teams' mean counts of the number of posts per case problem that included each of the Cofl

social presence indicators. The variances of the distance and blended groups were not equal for any of the indicators (see Table 29). The *t*-tests indicated that the mean number of posts per case that included the cohesive and affective indicators was significantly higher ( $p < 0.05$ ) for the distance teams than the blended teams (see Table 29 and B14 in Appendix B).

Table 29 *Descriptive Statistics for Cofl Social Presence Indicators for Distance and Blended BSc Students in an Online Problem-Based Learning Activity during an Ecotoxicology Course*

	Program	<i>N</i>	Mean	Std. Deviation
Affective	Distance	60	7.83*	6.22
	Blended	76	0.32	0.83
Cohesion	Distance	60	40.00*	18.83
	Blended	76	7.31	6.72
Open	Distance	60	5.30	8.66
	Blended	76	3.97	4.55

\* Independent samples *t*-test are significantly different at the  $p < 0.05$  level.

### ***Mixing Cofl and CLS coding schemes.***

The combination of various coding schemes provided some useful insights into the discussion forums, and allowed a closer examination of some of the impressions that were developed when reading through the discussion forums. The sections below provide examples of the combination of the Cofl cognitive indicators with the citations LS indicators; as well as the Cofl social cohesion indicator with the collaboration indicators.

#### *Exploration and integration posts containing citations learning scaffolds.*

One of the impressions that the investigator gathered during the initial read through of the discussion forums was that for the distance teams, the forums were a

place where they exchanged ideas and discussed each other's posts; whereas for the blended teams, the forums were the locations where they dropped off their portion of the assignment so that the moderator could collect it to integrate into the final report. As noted in Table 30, for the distance teams, approximately one quarter of the 1861 exploration posts and nearly forty percent of the 1535 integration posts contained citations. These teams discussed ideas more explicitly on the discussion forum, resulting in posts that integrated not only literature information, but also the personal ideas, work experiences and viewpoints of the team members that may not have been accompanied by citations. In contrast, nearly half of blended students' 1486 exploration posts and three quarters of their 1125 integration posts, contained at least one citation, and it was not unusual for there to be next to no discussion on the forum. This is consistent with the impression that the discussion forum was being used as an information collection point, with the discussion of ideas occurring offline. Interviews confirmed that blended students were likely to have face-to-face meetings to clarify and discuss ideas.

Table 30 *Number of Posts in the Exploration and Integration Categories That Also Contain Citations to Source Material during an Ecotoxicology Course*

Program	Exploration posts with citations	Integration posts with citations
Distance	445 (23.9%)	588 (38.3%)
Blended	652 (43.9%)	836 (74.3%)

***Posts with social cohesion and collaboration indicators.***

Although many messages did not have salutations or other indicators of cohesion, one of the observations from the content analysis was that students seemed to use salutations that included individual's names either when they asked questions of them or when they assigned individuals a specific task (or asked them to provide updates). For example, "Joan...would you please do this task? or "Grant, when will you post your table?". It was also noted that students who were moderating tended to ask

questions of the group. In order to test whether or not the use of cohesive indicators (salutations, most commonly) varied with the collaboration indicators of asking questions or moderator, the mean number of occurrences of cohesion, moderator and asking questions indicators used per team in each case were calculated (see Table 31), and used to determine if these indicators varied together (see Table B15 in Appendix B for descriptive statistics). The strong significant correlations between these three pairs of indicators agreed with the observations that questions or moderator comments were often addressed to specific individuals or groups of individuals.

Table 31 *Correlation Analysis for the Correlation Analysis of Two Collaboration Categories (Moderator and Ask Questions) with a Social Indicator Category (Cohesive) during an Ecotoxicology Course*

		Moderator	Ask Questions	Cohesive
Moderator	Pearson Correlation	1	0.744**	0.794**
	<i>p</i> (2-tailed)		0.000	0.000
	<i>N</i>	136	136	136
Ask Questions	Pearson Correlation	0.744**	1	0.820**
	<i>p</i> (2-tailed)	0.000		0.000
	<i>N</i>	136	136	136
Cohesive	Pearson Correlation	0.794**	0.820**	1
	<i>p</i> (2-tailed)	0.000	0.000	
	<i>N</i>	136	136	136

\*\* . Correlation is significant at the  $p < 0.01$  level (2-tailed).

## Interviews

Interview results were used to help explain some of the observations in the thread maps and content analysis. In some cases, these observations and explanations were mentioned in the above sections where appropriate. In spite of the small sample of

four interviews (two interviewees from each of the 2010 distance and blended cohorts), the interviews provided some useful insights into the team process for online PBL case problems. A summary overview of the recruiting process, interview length and member checking can be found in the description of the Interviews section found at the beginning of this chapter. All quotations from the interviews were used with the permission of the interviewee, and pseudonyms are used throughout the document. A summary of interview results is provided below.

### **Work experience and its influence.**

The interviewees all had five to fifteen years of work experience prior to starting their BSc programs, but the two interviewees from the blended program (Bob and Bev) did not have science or research based experience. Both Dean and Don (distance program) had more than 10 years of relevant course-related environmental work experience in environmental compliance and sampling, and environmental consulting respectively.

Interviewees generally found that they brought practical aspects of their past experiences to the assignment. Although he didn't have any science or research-related work experience, Bob felt his experiences working with people were useful to the team process. He felt that those students "that had more life experience and work experience managed the teamwork better...It was that experience that brought a bit more awareness outside of yourself and be able to work with a team". By contrast, Bev didn't feel that her past experience was particularly helpful, as it didn't include science or research-based aspects. Dean felt that his past experience allowed him to better visualize the scenario. He felt that this allowed him to better support his teammates by pointing out that "this is the big picture and don't forget the Ministry of Environment is going to be interested or something. I know just from having worked in it." Don felt that his industrial experience was helpful, as it related to toxins in the environment and allowed him to better explain aspects of the scenario and what was needed to address them.

**Posting behaviour.**

Posting behaviour by the interviewees was dictated by personal study requirements. Bev was not someone who posted first – she felt she needed time to consider ideas before posting. Dean tended to choose a specific time to do research and homework which resulted in many posts over a few hours, as his research coalesced into ideas to post. Don tended to post close to the deadlines because he wasn't as strong in this course as others, and took his time in getting help from his study group before posting. Bob tended to post early both to get the team started in the discussion and because he preferred to start his research immediately. Although all interviewees were comfortable in the online environment, Bev also stated that when she started the program, she didn't really have solid skills using many online tools and felt that this influenced her desire for face-to-face communication. She also stated that "if I was to try now to enter into an online learning sort of program, I think I'd do a lot better with the tools that I've developed since I've started with [this company], or basically since I've entered the workforce after my program."

**Citations learning scaffolds.**

It was an instructional design goal for the course that students read widely within the literature for the field. Addressing the PBL case problems thus required students to find and use a variety of different source materials including: lecture notes, websites, textbooks, etc. The content analysis suggested that students were reading widely. Interviewees were asked when and how they used the various possible learning scaffolds (source materials). Bob started his research with the materials that were provided (lecture notes, textbook and suggested websites) and then moved onto finding more sources once "we started putting [the solution to the case problem] together and analyzing it that we started thinking outside that box and started pulling additional resources that we felt needed to be filled in." Bev found that she used the lecture notes extensively, and was then "doing a lot of research, looking for some peer-reviewed literature." She noted that she didn't often use the course textbook. Dean used the lecture notes and the textbook as jumping off points for further research in the literature. Don noted that he started with the lecture notes because they "focused on some of the

stuff we were going to need as well.” He then moved to the textbook and other research materials. The common theme was the use of lecture notes and the textbook as starting points before moving onto personal research as they delved further into the PBL case problem.

### **Group discussions.**

Group discussion is an important aspect of PBL case problems – team members build and critique ideas through discussion. All interviewees mentioned that discussion between team members was an important aspect of their learning, and that it occurred more frequently in smaller subgroups that developed within the larger teams. In the blended teams, Bob and Bev indicated that they had more discussions with their small subgroups, which met frequently to clarify ideas and move ideas forward. Bob mentioned “We met a lot. But it fed into getting the clarification in getting to move forward. Had we not met so much, I think that we would not have been able to finally put anything together.” He was aware of the lack of online discussion by his team, as he noted “I think what happened was the moderators would put things out occasionally to draw more information out. But it wasn't a discussion, it was more of a one way could you give me more.” In a similar vein, Bev stated “talking to others and learning from them is pretty huge, it's a huge part of learning...You had to go through it a few times with people and talk about it until you understood it.” In the distance teams Dean agreed that discussion has an important place in teamwork “So you do a little bit of back and forth just to make sure you've got it straight as to what they've got or what they are working on so you can say, okay once you've got that, I can use that and so on.” He also mentioned that his offline discussions via email were primarily within the smaller subgroup that he tended to work with rather than the entire team. Don noted that “usually there was a pretty good network of people. You know, like groups of friends. Everyone had their own groups. It seemed like there were lots of people on Skype, who were my go to people. It was definitely like after hours or whatever time of the night, and that would be when I would bounce things off of people.”

### **Team approach to the PBL case problems.**

Interviewees confirmed that both distance and blended teams had an initial meeting for the purposes of getting organized, delegating responsibilities, and resolving any initial confusion. Bev noted that setting internal deadlines was also involved. She stated that “so there was probably face-to-face time first, and then people kind of went off, did their own thing, worked in their smaller sort of focus groups.” Bev didn’t have an example of what happened if a deadline was missed, as she said this didn’t actually happen in her team. Bob mentioned that deadlines were actually negotiated (e.g. how much has to be accomplished? What needs to come first?) Group discussions occurred around realistic timelines and how to prevent “scope creep” of the project.

Bob noted that the initial meeting involved “grasping the grand scope” of the project and negotiating timelines. Bob also mentioned that in his blended team individuals were “assigned specific questions to look at so that posts were being useful to the end result.” Bob also said “we were adding to the document as a whole with those posts.” This statement agrees with the investigator’s observation that Bob’s team was using sectional assembly to put together their report documents for the case problems.

Dean’s team (distance) had “some people who were naturally coordinators and they helped to divvy [sic] things up a little bit. And people would sort of volunteer as well to what they would like to do”. He mentioned that the person in his team with the strongest organizational skills set up a schedule at the start of the first PBL case problem, as well as organizational posts in the discussion forum because she felt this was a good approach. The team was happy to go along with this approach and she continued in this role through all four PBL case problems setting up organizational posts even when she wasn’t moderating. Although this activity had the potential to cause conflict, in this case, the team was happy to have her fill this organizational role. Don (distance team) mentioned that for his team, the approach was to “try to assign people tasks that aligned with their strengths”.

So, overall the initial meetings helped teams assign work, clarify ideas, identify internal deadlines and agree on an overarching plan. It should be noted that meeting offline was a common approach that occurred throughout the PBL case problems and was mentioned by all interviewees. These meetings were

a really interesting thing with the subgroups, and trying to come together with what they'd come up with and then try to get a consensus with the whole group based on what the subgroups had, that was a bit challenging. (Bob, 2010 blended student).

Most meetings early in the case problem were purely organizational rather than research based, i.e. getting organized, seeing where everybody was at, making sure that everybody was on track and on task theoretically, and clarifying whether anybody had confusion about the material or what they were doing. Subgroups were mentioned by all four interviewees. In the distance group, the subgroups tended to be based on who had media in common (e.g. Facebook and Skype) or who they had worked closely with in previous courses. In the blended program, the subgroups tended to be based on the small (three person) groups used for laboratory work in the course.

Most interviewee's indicated that they felt that their team approach remained consistent as the team progressed from PBL case problem one to four. Dean's team had evidence on the discussion forum of moderator-provided feedback on their approach. In the case two forum, there was a discussion on how to improve their team performance. Two areas of concern were identified: how to have everyone sign off on the final report; and how to ensure timely completion of the portions of the case problem that required work by others. Dean stated that while these concerns were identified on the forum, the majority of related conversation actually happened offline. He noted that

if things aren't going well or something is kind of getting a little bit tense or something like that, somebody's going to come along and say, 'Let's do better'. It's the kind of thing where maybe two people who tend to chat a lot would sort of go by each other and chat all about it and say 'let's go tell so and so and make sure we do this this way next time'. I can see that kind of thing in sort of side conversations and pull together another person that's perhaps a leader how you'd see it, and between the three of you you'd go and say, 'make sure you tell everybody and away we go'. And that would then be the plan right, this is how we're doing it.

This is in agreement with the investigator's observations that in general, any conflicts that arose in the teams were not typically visible in the online environment,

although two interviewees mentioned conflicts occurring in their teams. The common sources of conflict that were mentioned included: individuals that pushed for control of editing or moderating when it wasn't their turn; not meeting team deadlines; and trust issues around work quality.

### **Undocumented resolution.**

The investigator noticed that there were a number of posts in each of the case problems that invited comment, but there were no comments made on the actual discussion post at all. In some instances, these were questions and in others, requests for feedback. Bob indicated that although these posts may not have been responded to in the discussion forum, they were probably addressed in a face-to-face meeting if they were important. Requests for feedback may or may not have been addressed, depending on how close the request came to a deadline.

### **Moderation approaches.**

Each of the interviewees had slightly different ideas about how their approach changed when they were responsible for moderating. Bob felt that moderating required more direct requesting of what you wanted and needed from the team. For example, "I need a little bit more of this, or more of that. Or what did you mean by that?" Bev felt that she "probably tried to be more prepared, have a really good understanding where I thought the conversation was supposed to go so I knew how to guide it. I suspect I probably put more preparation time into that one."

Don thought he placed more emphasis on doing collaborative things but less on content - "I think my personal posts were probably less but I do believe that I probably engaged people more in a pseudo discussion." Dean mentioned that it "comes down to you're the one putting together a single unified document. You have to make sure you watch what's coming in, and being ready to plug it in or get help, or ask for help from so-and-so for help with that particular information." Dean also mentioned that he felt that he pulled back a little when not moderating to allow the person that was moderating a chance to practice leadership skills and direct the team format. He said, "Definitely when you're moderating the one thing I found you have to step up and say 'okay, this is my time'. Where I can display what I've learned or what I know, and get it done how I want it

done. There was lots of times out there where, I think a lot of people felt this way that maybe had somewhat of leadership positions before, where really if it's not your turn to moderate, or if there's a group and everybody has different ideas you sort of have to go with it.”

All interviewees expressed that they felt they had greater creative control of the final document and made more effort to be collaborative when they were moderating compared to when they were not.

### **Document assembly.**

Bob’s team used sectional assembly. He said that the small groups used a very collaborative process to assemble their sections, which were passed to the moderator for final assembly. The sections were edited prior to sending them to the moderator, but after the sections were handed to the moderator, the final document assembly was a less collaborative process. “We were confident in our content and how it got put together within our small group. So we didn't do a lot of revisiting it to make sure they edited it or they edited it appropriately.” The moderator assembled the three sections into one larger document.

Bev’s team also used sectional document assembly. Her team had an initial meeting and then organizational threads were started where needed by a member of the subgroup rather than the moderator. The smaller groups were responsible for assembling their sections before passing to the moderator.

Don’s team used end point assembly. They had one individual who had to be the final editor – not because this individual was necessarily any better at editing than any other team member, but rather insisted upon it.

Dean’s team used Google Docs for PBL case problems one, three, and four. It appears to have been suggested initially by one individual, but taken on board by the team. When asked why the team didn’t use it for case problem two, Dean said, “I’m not actually sure why we wouldn't have used it still. The reason we liked Google Docs I think was because everybody can edit it, or see who is editing it and have access to it at the same time.” The investigator pointed out that there had been a major error of omission in the case problem one report, but while Dean suggested that it may have

been the result of one individual failing to follow through on their portion of the teamwork, he wasn't sure.

**Concluding remarks.**

The Cofl cognitive presence indicators were successfully applied to the PBL discussion forums and with the addition of the organization indicator and the adjustment of the resolution indicator, the number of posts that fell into the *other* category was minimized. When the coding for the Cofl cognitive indicators was imposed onto the thread maps, they helped to highlight the two major approaches that students were taking to the discussions (organic versus organizational scaffold) as well as some of the other observable patterns of online behaviour that could be explained by the analysis of the content of the posts and confirmed by interviews in some cases. Quantitative comparisons were made between the distance and blended groups with respect to their FE-PBL and PBL-CT scores, how they changed over time, and in response to instructional changes. A CLS coding scheme was developed to assess both collaborative interactions within teams as well as use of the literature by their students to scaffold their learning. Comparisons were made between use of CLS indicators by distance and blended students. A discussion of the implications and interpretation of these results will be presented in chapter five.

## Chapter 5 Discussion

This mixed methods study makes comparisons between distance and blended undergraduate environmental students at Royal Roads University (RRU) as they participated in online asynchronous PBL case discussion forums as part of an Ecotoxicology course. The investigator taught all the cohorts that were involved in this study via distance or blended delivery. This study examines the differences between distance and blended teams in their activity, approaches, and levels of critical thinking in asynchronous online PBL discussion forums. Distance and blended students were also compared with respect to their use of learning scaffolds and evidence of collaboration. It should be emphasized that the purpose of the comparison is not to assess the relative efficacy of distance versus blended instruction, rather the purpose was to try to determine the source of the observed differences and how to best support distance and blended students for online PBL learning.

This chapter begins with comments on the study populations and data sources. This is followed by a discussion of the choice of the unit of analysis for the study, modifications that were made to the indicators included in the Cofl cognitive presence indicators scheme and comments on coding consistency using the modified indicators. A discussion of the quantitative results (including the descriptive and inferential statistics) used to determine the variability between cohorts, as well as the variability between the distance and blended groups will be presented. The thread map results are analyzed followed by a description of the content analysis results that lead to the development of the CLS coding schemes. This will be followed by an examination of the relative use of collaboration and learning scaffolds (observed using the CLS indicators) by distance and blended teams. Interview results are included whenever they explain the observations of other analyses rather than as a separate section. Reflections on how these results and observations address the research questions that guided this study will be included in chapter six.

## **Study Populations and Data Sources**

### **Study populations**

The investigator's experience over the past seventeen years teaching both distance and blended cohorts within the RRU BSc programs in Environmental Management and Environmental Science has yielded several informal observations about students who typically enroll in these programs. The undergraduates who pursue studies via distance education at RRU are typically looking for practical information, and have work and family commitments that make it impossible to travel to Victoria to pursue their studies in a traditional university (in this case blended) format. In contrast, the blended students are usually without work experience in the environmental field. The blended students do not typically have the same work and family commitments as the distance students, and as a result, are more able to relocate for work following completion of their program of study. These observations were in agreement with previous studies that showed significant demographic differences between distance and face-to-face students (e.g. Diaz & Cartnell, 1999; Tallent-Runnels et al., 2006). These studies also noted that distance students are also highly motivated students who often have specific learning goals that they wish to achieve from their educational experience (Diaz & Cartnal, 1999; Tallent-Runnels et al., 2006).

### **Data sources**

Both the distance and blended programs are taught in a cohort model at RRU. This means that all students in a given program take the same courses together at the same time. This approach results in a tight-knit community forming within each cohort that is well established by the time the students take the ecotoxicology course near the end of their respective programs (90 % complete for distance students, 80% for blended students). A previous study of RRU student cohorts suggested that the social relationships that developed within the cohort "aided the students in helping each other with the stress which can occur in education, particularly in DL [distance learning] courses", and was felt to be a major factor contributing to the 80 -100 percent program completion rates reported by RRU program directors (Guilar& Loring, 2008). This assessment is also in agreement with the investigator's instructional experience that

very few students drop the course (typically one student from each program included in this study), resulting in a very high course completion and student retention rates for students in the final year of both the distance and blended programs.

### ***Archived discussion forums***

All available discussion posts by the members of the distance and blended student cohorts were included. Reading the discussion posts while teaching Ecotoxicology made the investigator curious about why the online PBL activity seemed to be different for distance and blended cohorts.

### ***Interviews.***

The interview invitations were extended to the 2010 distance and blended cohorts well after the students had completed their respective programs via a voluntary email list maintained by the program office. Former students from both the distance and blended programs are often difficult to stay in contact with as they originated from all over Canada, and it is not uncommon for them to change locations or change employers (and thus change email providers) when they complete their program. Several students from each program were also known to be working internationally, and their emails bounced back. Although the number of interviewees was small (two per cohort), they did provide insight into the teams that the interviewees were members of, particularly with respect to behaviours that were either unresolved or invisible in the PBL case discussion forums. The interviews also helped to confirm the investigator's interpretations/hypotheses about the meaning of some forum activities. The interview results are not shared in isolation, but rather they are shared as part of the discussions on the other data sources to augment and support reflections.

### **Quantitative Component**

This section begins with a discussion of the choice of the unit of analysis; initial adjustments to the Cofl cognitive presence indicators; and coding consistency. The variability of the FE-PBL and PBL-CT scores for cohorts that make up the distance and blended groups are examined next, followed by comparisons between the distance and blended teams with respect to their posting behaviour, and PBL-CT scores. An

examination of how distance and blended team's PBL-CT scores changed over time and in response to instructional changes completes this section. The Quantitative Component of the study suggested directions for the Thread Maps and Content Analysis and informed the development of the interview questions.

### **Unit of analysis.**

This section discusses the considerations that entered into the choice of the unit of analysis for the study including the ability to consistently recognize it, the size of the resulting data set, and the ability to code posts that did not contain text. The choice of the unit of analysis for the coding using the Cofl cognitive indicators is then examined. The section concludes with a discussion of why a different unit of analysis was appropriate for coding using the CLS indicators and the Cofl social indicators.

The content analysis for the asynchronous online discussion form required the investigator to choose the unit of analysis – that is, would the coding be applied to sentences, paragraphs, messages or themes (Rourke et al., 2001)? The use of themes as suggested by Henri (1992) is problematic because themes don't correspond to a defined length of text in a message; a theme may be captured by a few words, a sentence, a paragraph or an entire message (Rourke et al., 2001). This is a major criticism of Henri's method as it decreases the consistency both of the analysis overall and of different coders recognizing a similar unit of analysis (Rourke et al., 2001). Compared to the use of themes as coding units, the use of units such as sentences or paragraphs would seem to be a more straightforward approach for a consistently recognizable unit of analysis.

There are three major issues with using sentences or paragraphs as coding units when applied to online discussion posts: identification of the sentence or paragraph, size of the data set, and posts that contain nontext information like maps or photos. Identification of sentences or paragraphs can be difficult because student postings to discussion forums often "combine the telegraphic style of email with the informality of oral conversation" (Rourke et al., 2001). That is, student posts are not always written with clear sentence and paragraph structure, something that was frequently observed in the case problem discussion posts. The pseudo-example post below includes the

punctuation as might be placed by the student, and illustrates the difficulty that can arise with coding student posts based on sentences or paragraphs. The investigator could reasonably count this post as consisting of two paragraphs, or four sentences or two sentences:

Well, first this post said I wasn't sure what to do... then I reposted deciding to go back to sea otter... then I saw Danny's post and think that is a great idea, if you are willing to do that D????

A lot of my research would apply to the harbour seal so I would gladly take on that....

This variety in possible interpretations of the unit of analysis can increase the error in the content analysis by adding another layer of interpretation by the researcher, who may first have to interpret what a sentence or paragraph might look like. The second issue, the size of the data set, is a result of the fact that a single message may contain a single phrase or sentence, sentence fragments (as in the example above), several sentences, or several paragraphs, which would quickly lead to an enormous number of units to categorize and analyze. The final issue is that students posted messages that contained photographs, tables, sketches, or maps – some of which also represented instances of critical thinking, and would not be accounted for in a coding scheme that is based on coding sentences or paragraphs as the basis of the unit of analysis.

As a result of these factors, the investigator decided that the message would be used as the coding unit for the portion of the study that was based on the Cofl cognitive presence indicators. This approach has been successfully used by other researchers (e.g. Garrison & Cleveland-Innes, 2005; Meyer, 2003; Rourke et al., 2001) and has the advantages of being easily recognizable by anyone. The use of the post as the unit of analysis also results in a manageably sized data set that contains both the manifest and latent content contributions in a package determined by the message author (Rourke et al., 2001). This approach also allowed the investigator to code messages that contain non-textual information (e.g. tables, photos, maps, etc.). These advantages contributed to the reliability of the study by allowing consistent recognition of the unit of analysis and

comparison to studies by other authors (e.g. De Wever et al., 2006; Garrison et al., 2001; Meyer, 2003) that also used the message as the unit of analysis.

A different unit of analysis was needed for the CLS and social presence indicators coding schemes because a single message may include several different examples of these behaviours in the form of words, sentences or sentence fragments. These smaller units were used for analysis as it was useful to be able to determine the frequencies for different indicators within a single message. Also, the categories of the CLS coding schemes are not mutually exclusive the way that the cognitive presence categories of the Cofl model are when used with the coding up/coding down procedure (Garrison et al. 2001, p. 17). That is, the presence of a citation to a textbook does not preclude that the message may also contain a citation to a website or reference to a student's work experience; whereas a message can only be categorized as fitting one of the cognitive presence categories as described and applied by Garrison et al. (2001).

#### **Archived discussion forums - initial coding adjustments.**

The very large number of posts that were being coded to "other" during the content analysis (55.52% of distance posts and 24.23% of blended posts fell into this category) brought into question what was being captured by the "other" category. When the content of these posts was re-examined, it appeared that these posts gave structure to the discussion or negotiated how the group was to work together, but didn't fit into the cognitive presence categories of triggering, exploration, integration or resolution that the other posts fit easily into.

Similarly, these organizational posts did not fit into the social presence (open communication, group cohesion, or affective expression) or teaching presence (design and organization, facilitating discourse or direct instruction) parts of the Cofl model (Garrison & Arbaugh, 2007). The design and organization category of teaching presence describes "planning and design of the structure, process, interaction and evaluation aspects of the online course" (Anderson et al., 2001; Garrison & Arbaugh, 2007) and at first glance, appears to be a possible fit for these posts. However, because the design and organization category captures activities of the instructor rather than the students, it suggested that an additional category, "organization" within the cognitive presence,

would be useful to capture these behaviours when performed by a student. As noted by Vaughan et al., "All participants in a collaborative learning environment [like a PBL team] must assume various degrees of teaching responsibilities depending on the specific content, developmental level, and ability" (2013, p. 14). The organization indicator within the cognitive presence domain helps to capture peer-to-peer organization that contributes to the cognitive functioning of the group.

Organization posts appeared to serve an administrative function that required planning and critical thinking, suggesting that this category belonged within the cognitive presence rather than the social presence part of the Cofl model. This conclusion is supported by Bloom's taxonomy, which indicates that planning and reducing larger tasks to smaller subunits involves higher order thinking (Krathwohl, 2002). The organization posts were not included in PBL-CT index because the posts often contained no text at all, with the hard scaffolds from the problem being used as the title of the post. The timing, context and content of organization posts were often a key to determining how a team was working together and what approach they were taking to the task. Behaviours observed in organization posts included volunteering to research a topic, setting deadlines, dividing the large task into smaller ones, using hard scaffolds from the problem to organize the threads of the discussion, setting up offline meetings, etc.

Interviews indicated that although student moderators usually were responsible for making organization posts, they could also be made by members of the team who had strong organizational skills (Dean, 2010 blended student interview). The addition of the organization category greatly reduced the number of "other" posts, and provided information on how the group was working together.

In Table 32, the portion of exploration and integration posts appears smaller for the distance group than the blended group. The large number of posts by distance students as compared to blended students makes the data seem skewed at first glance. In Garrison et al. (2001) and Meyer's (2003) studies, only the triggering, exploration, integration and resolution categories were included in cognitive presence with the highest number of posts in the exploration and integration categories. The current study is in agreement with those results as the exploration and integration categories

represent the most frequently identified categories of the group by both distance and blended students (see Table 32) with the numbers of posts in these four categories having a similar order of magnitude. The large difference in the number of organization posts between the distance and blended groups supports the investigator's impression that distance students do more planning and administrative tasks on the discussion forum than blended students. This result cannot be directly compared to previous studies because posts that were coded as organization in the current study were likely included in the social or other category by previous authors. Table 32 also highlights that although the percentage of the total posts in a particular category may be lower for the distance group than blended group, the much larger number of distance posts than blended posts (8313 versus 3671 respectively) still results in the actual number of posts in most categories being larger for distance than for blended posts.

Table 32 *Comparison of the Percentage of Total Posts in Each Cofl Category for Meyer (2003), Garrison et al. (2001), and the Current Study*

	% total posts			
	Meyer	Garrison	Distance % (N)	Blended % (N)
Triggers	18.18	8	0.4(33)	1.3(48)
Explorations	50.59	42	22.4 (1861)	40.5(1487)
Integration	22.24	13	18.5 (1535)	30.6(1126)
Resolutions	6.66	4	3.2(269)	3.2(119)
Organization	NA	NA	47.0(3910)	21.0(772)
Social or other	3.33	33	8.5(705)	3.2 (119)
Level	Graduate	Graduate	Undergraduate	Undergraduate
Discipline	Education leadership	Education health promotion	Ecotoxicology	Ecotoxicology
Total postings	751	94	8313	3671

\* numbers in brackets are the total counts for that category.

Garrison, Anderson and Archer 2001 describe the resolution category as being indicated by posts which defend possible solutions, test solutions or exhibit a vicarious application to real world situations. Their behavioural example indicates that the student will specifically identify the post as a solution and suggest how that solution might be tested (Garrison et al., 2001). Although students may make posts that fit this example for problems that have a definitive “solution”, students may be less willing to explicitly label their posts as solutions to dilemmas or decision-making problems where the solution is less clear cut. For dilemma and decision-making problems, resolution may involve the group reaching a consensus rather than a solution per se (Garrison et al., 2001; Jonassen, 2011). The investigator felt that the resolution category should also include posts by a moderator that are a draft of the final report write up – in effect, the draft is a proposed solution for team consensus to the problem of the assignment. Testing and defending various aspects of the solution (resolution) may also take the form of other members of the group putting forward substantive changes to this draft. Therefore, the characteristics of what a resolution post is can vary based on the type of problem posed by the instructor and the deliverable that is required from the students (Jonassen, 2011).

It is also of note that in contrast to other studies (e.g. Meyer, 2003) the authors of all posts were identified, making it possible to identify instructor posts and student responses to the instructor. In Meyer’s 2003 study, the discussion forum data was anonymized prior to analysis. As a result, the instructor posts were also included in the analysis and could not be distinguished from the student posts (Meyer, 2003). It is possible that instructor posts may be contributing to the larger proportion of triggering posts observed in this study.

### **Coding consistency.**

This study utilizes a single coder because it is an example of a self-study. Self-study is a useful form of practitioner research in which the investigator examines the “knowledge and learning derived from researching their own [teaching] practice.” (Loughran, 2009, p. ix). Although inter-rater reliability is a common method of evaluating consistency when coding is done by more than one researcher, in a self-study context

this is not possible. Lassonde, Galman & Kosnik point out that in contrast to self-study research, “historically validated forms of research [e.g. inter-rater reliability] often do not allow researchers opportunities to closely examine their own work thus limiting its value for improving practice. Many teacher educators believe that studying their own practice is essential.” (2009, p. xi). As one of the goals of the project was to ultimately determine how best to support the learning of students in the PBL activity, the self-study approach is a good fit with the mixed methods approach used.

Because only a single coder was used, the approach taken by Rourke et al. (2001) was adopted to evaluate coding consistency over time. The posts for the distance 2004 and the blended 2004 cohort were coded and then re-coded on two separate occasions after the initial coding was done (primarily to accommodate ad hoc adjustments to the coding scheme, but at least partially to confirm coding was consistent). As there were very few changes required in the first re-coding (12 out of 1803 posts) and no changes required in the second review, it appears that the coding consistency was very good over time.

#### **Variation within distance and blended groups.**

The online discussions conducted by the distance and blended students appear to be substantially different, and the intent of the research questions was to investigate the factors that contributed to the difference. To support making comparisons between the distance and blended groups, it was necessary to determine how much variability there was within the distance and blended groups with respect to their scores on the scenario portion of the final exam (FE-PBL) and their level of critical thinking expressed in the PBL case discussion forums (PBL-CT).

It was hoped that the four cohorts that made up each of the distance and blended groups would be similar enough to be considered as samples from single populations. To test this idea and gain insight into how similar cohorts were to one another within the groups, the four cohorts were compared with respect to their FE-PBL scores and PBL-CT scores using ANOVA. The following two subsections discuss the results of the ANOVA testing.

### ***Final exam scores (FE-PBL).***

By 2002 a scenario problem designed to be similar to the PBL case challenges used in the course was included as part of the final exam. This decision was based on indications in the PBL literature that students' performance on exams that were similar to the PBL problems was better than on general exams (Dochy, 2003; Gijbels et al., 2005). The cohort mean scores on the PBL-like portion of the final exam (FE-PBL) were marked out of 110 possible points and were compared using ANOVA analysis to examine the variability within cohorts that make up the distance and blended groups.

The 2004 distance cohort had a higher mean score and lower standard deviation than the other three distance cohorts (see Table 2). This difference was shown to be significant at the  $p < 0.05$  level (See Table 3), while the other cohorts are more similar to one another and to the combined mean. The exams were very similar from year to year with the differences being related to the contaminant of interest in the PBL scenario, so differences in the exams did not seem to be the source of the difference. The final exams are not returned to students nor are previous exams available to students for study purposes, so availability of previous exams is also not a factor. The same contaminant was used in the 2004 and 2010 PBL scenarios, so the use of the contaminant also does not seem to be the cause. One possible explanation is that the 2004 distance class was a particularly strong academic class with no struggling individuals. In the 2004 distance cohort, the FE-PBL scores ranged from 75 to high 90's, while in each of the other cohorts, the FE-PBL scores within each class ranged from around 55 to over 90 points.

The 2004 blended cohort also had the highest mean FE-PBL score of the four blended cohorts (see Table 4), and it was significantly different at the  $p < 0.05$  level (see Table 5). Similar to the 2004 distance cohort, the 2004 blended cohort was academically strong, with no individuals who particularly struggled with the course. In fact, the 2004 blended cohort included a student who went on to win the Governor General's Silver Medal at convocation. In contrast, the 2009 cohort was a weaker academic group with more students who struggled with the course. Scores contributing to the means were more tightly clustered for the 2004, 2009 and 2010 cohorts than the 2006 cohort (see Table 4). The 2006 cohort had FE-PBL scores that ranged from failing

grades (below 55 points) to a perfect score (110 points), resulting in a higher variance than the other cohorts in the blended group. An ANOVA analysis combined with a Fisher Least Squared Difference post hoc test also indicated that the mean FE-PBL score for the 2006 cohort was significantly different from the 2004 and 2009 cohorts, but not from the 2010 cohort (see Table 4, 5, and B2 in Appendix B).

Although it was initially hoped that the ANOVA tests would show that the mean scores for all four cohorts were equal within the distance and blended groups, it was not surprising to see such variation between cohorts. The investigator has observed that even when the same instructional materials are used, there are stronger and weaker classes over time that take the course. These variations reflect not only the academic strength of individual students but are also influenced by a student's relative connection with the instructor and their teaching style, as well as study habits, and outside influences on the student's life (work and family considerations). The higher marks for the 2004 cohorts were unlikely to be an example of grade inflation due to the instructor "working out the kinks" in a new style of exam as the PBL-like scenarios were included in the final exam on three occasions (two cohorts in 2002 and one in 2003) prior to their use with the 2004 distance and blended cohorts that were included in this study. Although the instructional materials for the 2004 cohorts do not show any obvious differences in how the course was taught, it is also possible the dialogue between the 2004 cohorts and the instructor may have somehow better prepared the students for the scenario portion of the final exam that year. Interestingly, the blended student's combined mean FE-PBL score was quite close to the cohort means for the 2006 and 2010 cohorts (Table 4), suggesting that four cohorts could be reasonably combined as a set. The investigator felt that it was reasonable to combine the four distance cohorts into a distance group and the four blended cohorts into a blended group in spite of the identified statistical variations in their FE-PBL scores because the study focuses on how the behaviour of the distance and blended students was different and could be best supported.

### ***PBL critical thinking scores (PBL-CT).***

Critical thinking in the asynchronous PBL case discussion posts was assessed using the cognitive presence categories of the Cofl framework as described by Garrison et al. (2001) and Rourke et al. (2001). Similar to other researchers (e.g. Garrison et al., 2001; Meyer, 2003; Rourke et al., 2001), the investigator found that categorizing the postings under the Cofl categories for cognitive presence was straightforward.

PBL-CT scores were generated by totalling the number of posts in the exploration, integration and resolution categories for each student across the four PBL case problem discussion forums. This index was useful as it evaluated a student's engagement over time in the course. The mean cohort PBL-CT scores were compared to examine the variability of the cohorts within the distance and blended groups.

The mean PBL-CT scores for the distance cohorts were similar, with the 2008 cohort having the highest mean and standard deviation (see Table 6). The ANOVA test demonstrated that means for the number of critical thinking posts for the four cohorts were equal (see Table 7), and can be treated as samples from the same population. The assignment had the same directions for all four cohorts, although the participation in the discussion forums (and therefore the pressure to post) was given a greater weight in the grading in 2008 and 2010 (10% of the total course grade vs 5% in 2004 and 2006). This change did not appear to have a significant effect on participation in the distance cohorts since the mean PBL-CT score was not significantly different after the change occurred.

The mean PBL-CT scores for the blended cohorts indicated that the four cohorts were split into two pairs – the 2004 and 2006 cohorts forming one pair and the 2009 and 2010 cohorts forming the second pair (see Table 8 and 9). The ANOVA results and Fisher Least Significant Difference post hoc test confirmed that the differences between the two pairs were significant (see Table 9 and B3 in Appendix B). The timing of this split coincided with a change in the course requirements for the blended classes. In 2009 the investigator added the following statement to the course outline: “There are four case studies, participation is mandatory for all four. *Note: if you do not participate in a particular case study, your grade for the team portion of the assignment [the PBL case report] will be zero.*”

The statement about participation being mandatory had always appeared in the course outlines from 2004 onwards for both the distance and the blended cohorts. However, the statement about receiving zero for the team portion of the grade was added following several student complaints from the 2004 and 2006 blended cohorts about teammates who did not participate in the discussion forum or contribute offline to the generation of the PBL case report still receiving a share of the grade for the team report. Making the penalty for nonparticipation more explicit appears to have increased the posting behaviour and thereby the mean PBL-CT score for the later blended cohorts by 200-300% compared to the earlier cohorts (see Table 8). This brought the cohort mean PBL-CT scores much closer to the scores for the distance cohorts. It had been assumed that offline activity was occurring frequently for the blended cohorts, and that all members of the team were contributing, even if their contributions were not observed on the discussion forum. Based on the student complaints about the inactivity of certain teammates, this was apparently not always the case. Although it was hoped that students would be intrinsically motivated to participate due to interest in the problems, the change in participation by blended students following this change in the instructions indicates that this is not always the case. Although the distance cohorts did not make similar complaints, the same statement was added to the course outline for the distance cohorts to maintain consistency between the two instructional models. The addition of this statement to the distance course outline did not have a noticeable impact on the cohort mean PBL-CT score for the 2010 cohort which was the only distance cohort that took the course after the change (see Table 6).

The ANOVA analysis of the distance cohorts' PBL-CT scores indicated that they could be considered to be samples from a single population. Although the ANOVA analyses of the PBL-CT scores of the blended students showed variation within the four cohorts, the investigator did not feel that the variation was unusual or precluded the four cohorts being combined into a larger group representing the blended instructional model. Guilar and Loring (2008) point out that it is not possible to "predict the needs, conversations, and events that make each cohort different. The informal, emergent community is both inevitable and desirable" (p. 34). These emergent properties of the

learning community can cause some groups to provide higher degrees of support to each other, and help the members to be more successful overall.

The students in each cohort chose their instructional model based on their personal assessment of what would best meet their educational, financial and personal needs. As a result, the students that chose each instructional model tended to have some characteristics in common (see Study populations). For example, students in the blended cohorts tended to be recruited directly from their college programs via transfer agreements, whereas students in the distance cohorts tended to be recruited via word of mouth or via web-based advertising, and generally had significant work experience in the environmental field. Although there were students in each cohort who did not fit these general characteristics as well as their colleagues, and there were some minor differences in the FE-PBL and PBL-CT results across cohorts, the investigator felt that the cohorts of students for each model could be reasonably combined into two larger groups. Therefore, the rest of the discussion is based on the comparison of the distance and the blended group's approaches to the online PBL work.

### **Comparison of FE-PBL and PBL-CT scores between blended and distance groups.**

The mean FE-PBL scores and the mean PBL-CT scores for the distance and blended groups were compared using independent samples *t*-tests. The FE-PBL scores were examined to see if the distance and blended groups were achieving to different levels overall on a single assessment and the PBL-CT scores were examined to see if the groups differed with respect to critical thinking on an assessment that required a sustained academic effort.

The instructor and the course design are not confounding variables – the same instructor and course design are in use for all cohorts of students in this study. In addition, the cohorts have been matched between the two instructional models (distance and blended) to ensure they used the same version of the PBL case study. This is notable as most other studies compare multiple classes that are taught by multiple investigators, some of which may be more or less successful (Diaz & Cartnal, 1999; McLinden et al., 2006).

***FE-PBL scores.***

An independent samples *t*-test indicated that the aggregated distance and blended group's mean and standard deviation for the FE-PBL scores were very similar (see Table 10 and B4 in Appendix B). The impacts of the higher and lower achieving students had less influence on the mean scores when determined by the larger combined distance and blended groups as compared to the cohort samples. This result indicates that the differences between the distance and blended groups' exam scores were minimal. Because of the significant split in the blended group PBL-CT scores between the earlier 2004 and 2006 cohorts versus the later 2009 and 2010 cohorts, an independent samples *t*-test was also done to compare the mean distance FE-PBL score with the mean FE-PBL score of the blended 2009 and 2010 cohorts. The conclusion remains consistent with no significant difference between the FE-PBL scores of distance group and the blended group ( $p < 0.05$ ).

***PBL-CT scores.***

The distance group's mean and standard deviation for their PBL-CT scores were higher than those of students in the blended program (see Table 11). An independent samples *t*-test demonstrated that the means were significantly different ( $p < 0.05$ ), with the distance group posting significantly more critical thinking messages than the blended group (see Table 12). Because of the significant split in the blended group PBL-CT scores between the earlier 2004 and 2006 cohorts versus the later 2009 and 2010 cohorts, an independent samples *t*-test was also done to compare the mean distance PBL-CT score with the mean PBL-CT score of the blended 2009 and 2010 cohorts. The conclusion remains consistent with the distance group posting significantly more critical thinking messages than the blended group ( $p < 0.05$ ). The students in the distance program had a more varied educational and work experience background than students in the blended program, which generally came to the program directly from their college diploma programs. The distance teams also use the discussion forum as a primary means of communication, and so likely had higher PBL-CT scores as a result of exchanging more ideas on the forum, whereas the blended teams were likely exchanging more ideas face-to-face. The variation in prior learning and communication

medium may have contributed to the higher standard deviation observed for the distance group as compared to the blended group (see Table 11).

***Combining exam scores and PBL critical thinking scores (blended vs distance).***

The combination of the *t*-test results for the PBL-CT scores and the FE-PBL scores gave some insight into the limitations of the PBL-CT scores for the blended group as compared to the distance group. Although the distance group posted significantly more messages that contain evidence of higher order thinking (higher PBL-CT scores), their exam results (FE-PBL) were not significantly different. This suggests that for blended groups, the learning activities were still taking place to a similar extent (and thus similar achieving exam results) although where those activities were occurring was different. For blended students, the critical thinking that went into the PBL case reports frequently occurred off the discussion forum. When asked about the lack of discussion in the PBL case problem discussion forums, Bev noted that “you just walk over to someone's desk and you just talk to them face-to-face about it. I don't ever remember the online forums being the main form of communication”. Therefore, for blended students face-to-face communication is a key component that cannot be assessed here. As a result the PBL-CT scores may not be as representative of the higher order thinking that is occurring for the blended teams as they are for the distance teams.

***Correlation between FE-PBL scores and PBL-CT scores.***

Previous studies indicated positive effects when the effectiveness of PBL compared to traditional classrooms was measured using performance/skills-based assessments or a mixture of knowledge and skills-based assessments (Gijbels et al., 2005; Strobel & van Barneveld, 2009); and that the form of assessment was critical to observing PBL effect sizes (Dochy et al., 2003). Because a student's PBL-CT score and FE-PBL could both be considered as independent indices of higher order thinking, a Pearson correlation was done to see if the two indices varied together for distance and blended students. It was determined that there was no correlation between the two

indices (see Table B5 in Appendix B). Interestingly, if the data for the 2004 and 2006 blended cohorts are omitted, the correlation becomes significant ( $r(182)= 0.186$ ,  $p=0.012$ ) (See Table B5).

The lack of correlation when the data for all the cohorts was included was a surprise. However, the significance of the correlation when the 2004 and 2006 blended cohort data is removed demonstrates that there is a relationship between these variables. These two cohorts had much lower PBL-CT scores than the 2009 and 2010 blended cohorts (see Figure 4), which appears to have masked the relationship between the FE-PBL and PBL-CT scores. The later blended cohorts were likely influenced by the change to the assignment description that has been discussed in previous sections. There are differences with respect to time, motivation and pressure associated with the two indices. The PBL-CT is an index of higher order thinking as expressed by student writing in the PBL case discussion forums. As a result, while it related to a student's thinking, it is also related to their level of online engagement and perseverance. When writing their discussion forum posts, students can research, discuss ideas with others and edit their posts allocating as much or as little time as they wish to the task of sense-making and communication with their team. In addition, not all students were equally engaged in their online discussions, especially within the blended cohorts, where considerable discussion maybe occurring offline, which would have decreased their PBL-CT scores without necessarily co-varying with their FE-PBL scores. In contrast, when working on their final exam, the student is working against a time limit with only the knowledge and skills that they individually possess at their disposal in a more pressure intensive situation. For those students who use the discussion forum as the primary medium to engage with their team, the PBL-CT related tasks would seem to be a more authentic reflection of working with actual environmental problems.

The investigator has since experimented with using PBL-CT scores to grade the critical thinking learning outcome for the course. Preliminary results indicate that the assessment scale (what score is needed for a particular letter grade) may require adjustment between distance and blended cohorts, to compensate somewhat for the lower online participation by the blended cohorts. It appears to be a more useful

assessment within a particular cohort than simply counting the total number of posts. It is uncertain whether providing a rubric explaining how the PBL-CT score is used to determine their grade would eliminate the need to adjust the assessment scale between distance and blended students. Because blended students still use face-to-face meetings as their primary means of communication, it may encourage students to consider posting to the discussion forum as “busy” work that doesn’t have intrinsic value.

### **Distance versus blended posts, threads and posts per thread.**

As noted in the results, the initial read through of the discussion forums gave the impression that the distance teams were posting more messages to the forum, and were more likely to actually be discussing ideas rather than just posting information for the moderator to assemble into the final case problem report document. Independent samples *t*-tests confirmed these observations. Distance teams posted approximately twice as many messages per case than blended teams, but interestingly organized their messages into the same number of threads. The threads used by distance teams were approximately twice as long as those used by blended teams, implying that the posts may have included more exchanges of ideas (see Table 13 and 14). This assessment was also supported by the observation that the longer threads characteristic of the distance teams often included messages from several different team members. In contrast, many of the blended team threads had only a single contributing author, and sometimes consisted of a single post.

### **Distance versus blended Cofl cognitive presence indicators.**

A series of independent *t*-tests showed that the mean number of posts in each category except for triggering was significantly higher for the distance teams than the blended teams (see Table B6 and Figure 3). The much higher activity in the organization category for the distance teams was attributed to the distance teams using the PBL case discussion forums as the primary mode of communication. As a result, activities covered by the organization category such as dividing up the work, deciding what approach to take and organizing the discussion itself had to be explicitly shared in the discussion forum for the distance teams. As confirmed by the interviews, these

kinds of activities were often done face-to-face for the blended teams, so it was often the case that there was no evidence of them on the discussion forums.

There was no substantial difference between the use of triggers between the distance and blended teams, with both groups using them infrequently. There are a couple of possible reasons that triggers were used infrequently by the distance and blended teams. First, for both groups, students tended to supply material with citations in a post as well as a statement that could potentially be a trigger. As a result, this kind of message was then “coded up” to an exploration post as per the recommendation by Garrison et al. (2001). A second reason that so few triggering posts were observed may be due to the way that hard scaffolds taken directly from the case assignment were used. Hard scaffolds were material that was quoted directly from the case that was used to set up threads or headings in the discussion forums. These hard scaffolds are not triggers because they do not fulfill the description of triggers by either explicitly asking questions or taking the discussion in a new direction (Garrison et al., 2001). In addition, these posts often contain no text in the body of the message at all, and the quoted scaffold text is used as the header for the message. These hard scaffolds were used to organize the discussion forum and will be further discussed in the section on organic discussions versus the use of organizational scaffolds. The number of hard scaffolds used was reduced as the students moved from case one to case four. Interestingly, the number of triggers remained very low as students progressed to case four, suggesting that the coding up to an exploration post was a more consistent influence on the low number of triggering posts observed than the number of hard scaffolds provided in the problem.

Similar to studies by Meyer (2003) and Garrison et al. (2001), the exploration and integration categories were used the most frequently of the original categories for both distance and blended teams. Again, the distance teams posted more messages per case than blended teams, which is also likely due to the discussion forums being the primary means of communication. In addition, distance teams more frequently assembled their final report documents on the discussion forum, which resulted in more integration posts (this will be discussed further in the section on document assembly).

Both groups had resolution posts as approximately 3% of their total posts (see Table 32) this means that because the distance teams published three times as many posts, there were approximately three times as many resolution posts when compared to the blended teams (see Table B6 and Figure 3). This is likely a result of the greater tendency of the distance teams to assemble their PBL case problem reports in the discussion forum as compared to the blended teams (this will also be discussed further in the section on document assembly). At the conclusion of each PBL case discussion, the moderators were to prepare and submit a summary report that addressed the question. One possible outcome of PBL and the need to generate a final report is that it may be helping to move the discussion to resolution. It has been noted by other authors that discussions can easily stall at the exploration stage (e.g. Garrison et al., 2001; Garrison, 2007; Garrison &Arbaugh, 2007). Garrison et al. (2001) note that “progression to the fourth phase [resolution] requires clear expectations and opportunities to apply newly created knowledge” (p.5). The requirement for the final report seems to have provided such an opportunity for students to integrate their own ideas as well as ideas from diverse source materials. The investigator observed that integration posts usually contained proper citations and fully formatted paragraphs so that the information was ready to be integrated into the final report. Interviews confirmed that the need to produce a final report was driving the discussion towards integration and resolution. Even when that resolution couldn't be observed in the discussion forum, as was the case for blended teams for 82% of the case problems, the case report was still completed, which indicates that the discussion to reach a consensus was continuing off the forum.

Social and other is a category that collected messages that did not fit elsewhere. These other posts represent messages that are social interactions such as off-topic discussions, jokes or other conversations. Xin and Feenberg (2007) point out that “the more deeply the participants interact, the more successful they will be in advancing the agenda of the course and achieving individual conceptual change” (p. 422). Both the distance and blended students had formed tight-knit learning communities at this point in their programs as is typical for RRU student cohorts (Guilar& Loring, 2008), and these close relationships help to support the team's learning. The distance teams

posted nearly ten times as many messages per case than the blended teams did in the social/other category; again likely because the PBL case discussion forums were their primary mode of communication, and they used social comments to reinforce their social dynamics (Garrison & Arbaugh, 2007). Because the blended teams could reinforce their social interaction in face-to-face meetings, they were less likely to make social comments in the discussion forum.

#### **PBL-CT score comparisons across case one to four.**

As students proceed from PBL case one through four, two major changes occur. Firstly, students become more experienced with working in a PBL environment, and are better able to identify information gaps/learning opportunities as well as how to fill them. Secondly, the number of hard scaffolds provided in the PBL cases decreases. The investigator chose to decrease the hard scaffolds provided as the cases progressed because it was felt that the students would become more independent over time and require less guidance. This instructional choice was later found to be in agreement with the literature that indicated that the PBL tutor needed to support students with information resources initially, and this support could be reduced over time as the students gained confidence in their abilities to locate and select their own resources (e.g. Barrows, 2002; Hmelo-Silver, 2004; Hmelo-Silver et al., 2007). Although it was possible for teams to reuse hard scaffolds from previous cases, this was not something that was observed in the discussion forums in this study.

The problems used in the Ecotoxicology course were examined with respect to Jonassen's problem typology (Jonassen, 2000) to attempt to determine if the problem type and scaffolding were changing over the course and what effect this might have had on the exhibition of critical thinking in the online asynchronous discussions. The overall design of the PBL cases in the Ecotoxicology course has not changed significantly over the years, but the wording and some of the included scaffolds have been tweaked over time. The four PBL cases used by the teams in this study were all focused on decision-making problems; however the last two cases also contained design elements.

***Distance cohorts.***

The results of the ANOVA analysis of the mean PBL-CT scores showed that the four distance cohorts were not significantly different at the  $p < 0.05$  level for any of the four cases (see Table 17). In case two, the 2008 cohort stands out as having a high mean and standard deviation compared to the other cohorts in this group (see Table 16). This cohort had a couple of outliers in the data set with two very low PBL-CT scores (scores of one and two) by students who posted very little, and two very high PBL-CT scores by students who posted a lot (scores of 53 and 35 respectively) compared to the combined mean for case two of 9.93 including the outliers with a standard deviation of 8.15. These outliers appeared to cause the higher than anticipated standard deviation and pulled up the cohort mean, as when these outliers are removed, the mean becomes 10.07 with a standard deviation of 6.88, which is more similar to the other cohort mean values for case two. Case two was also the only case in which the variances did not appear to be equal as confirmed by the Levene test for equality of variances (see Table B7), which was in agreement with the interpretation of the outliers. The graph of the cohort mean PBL-CT score for each case shown in Figure 4 confirms that for the distance teams the PBL-CT scores for each case were relatively consistent, with some variation in the case two PBL-CT scores. Although the problem types don't change from case one to four, the students do receive the marked reports for case one before they are required to hand in their second PBL case report (marked case reports are consistently returned before the next report is due). It appears that the instructor feedback provided on case one is more likely to result in noticeable changes to the team's performance than any other case. For example, changes in discussion approach, a better understanding of the amount of information needed to address the question or a better understanding of how much time commitment was required. This feedback may have also impacted the activity on the discussion forums. In addition, students may provide each other with informal feedback on the effort put forth on the first case problem discussion. This informal peer feedback was mentioned in the interviews by both distance and blended interviewees.

***Blended cohorts.***

The ANOVA results and the Fisher's Least Significant Difference results (see Table 19 and 20) confirmed the observation that the PBL-CT scores for the blended class were split into two groups made up of the 2004 and 2006 cohorts and the 2009 and 2010 cohorts. The differences were significant at the  $p < 0.05$  level. The overall PBL-CT scores for each case for the blended group showed a similar split as was observed for total PBL-CT scores within the blended group (see Table 8). This split may have been related to the 2009 inclusion of the statement in the course outline explicitly stating the penalty for not posting. Following the change to the wording in the course outline, the blended cohorts in 2009 and 2010 appeared to have achieved greater PBL-CT scores. In the 2004 and 2006 blended cohorts, the PBL-CT scores for case one and two were higher than those for case three and four. Although all the teams handed in PBL case problem reports of good quality, the 2004 and 2006 blended teams appeared to be less motivated to post to the discussion forums as the course progressed and they came up against deadlines for other courses. As they had the ability to have face-to-face meetings that were not captured by the PBL-CT scores, they did so. Some students were capable of strong FE-PBL scores even if they didn't have a significant online presence. These students may have been fully participating in the PBL discussions but in face-to-face meetings with their team. For other students, this was not the case as they had both limited online participation, and as implied by complaints from classmates, also limited face-to-face participation. The course outline change appears to have encouraged students to make a greater effort to post their ideas and research contributions to the discussion forums. Evidence for this conclusion is the higher PBL-CT scores for the 2009 and 2010 cohorts, and the more uniform PBL-CT scores as students in the 2009 and 2010 cohorts progressed from case one to case four as compared to the 2004 and 2006 blended cohorts.

***Distance versus blended PBL-CT score comparisons across case one to four.***

The independent  $t$ -tests showed that the differences between the distance and blended cohorts' mean PBL-CT scores were significant at the  $p < 0.05$  level for all four cases (see Table 22). Figure 4 demonstrates a few points of interest. First, the distance

cohorts had higher PBL-CT scores than the blended cohorts. It should be noted that the PBL-CT scores are based solely on the student's online activities and do not reflect any discussions or higher order thinking that may be occurring offline. Second, the split in the scores for the earlier and later blended cohorts was evident. And third, for any given cohort, the mean PBL-CT score for a typical student remained relatively consistent across the four PBL case problems (except 2004 and 2006 in the blended cohorts). This is of interest because the number of hard scaffolds within the PBL case problem was reduced as the teams progressed from case problem one to case problem four. As the number of hard scaffolds in the problems decreased, students needed to be more capable of identifying information gaps and how to address them. Other authors (e.g. Barrows, 2002; Hmelo-Silver, 2004; Hmelo-Silver et al., 2007) have suggested that as students become more familiar with the PBL process that they may require less guidance. It seems reasonable that it might be more than just a matter of becoming familiar with the PBL process – it may also require the students to become familiar with the course expectations through teaching presence expressed as timely feedback on the team PBL case problem reports. The case one team reports were typically not the strongest of the four PBL case reports as students were still in the process of building an understanding of instructor expectations, and had not yet received any feedback on case reports. It might also be expected that students could develop an informal feedback process to critique and improve their team process and effort.

### **Thread Maps and Content Analysis**

The qualitative analysis in this study consists of the thread map analysis and the content analysis. Both parts began with a read-through of the online discussion forums for each team, followed by the designated analysis. The results of these two parts are discussed separately below. This section also includes information from the interviews to help explain some of the conclusions drawn from the analysis of the thread maps and content analysis.

#### **Thread map analysis.**

Thread maps were constructed for each team and case problem discussion. The process was simplified as the compiled team discussion forums retained their thread

organization in which all posts were date and time stamped as well as identified by author. This was useful both in identifying interactions between students as well as between students and the instructor.

Patterns that were observed in the thread maps were examined in combination with the content of the messages to interpret the significance of the pattern. In some cases, interviewees' comments were available to confirm or expand on the interpretation. The observed patterns are discussed below.

### ***Getting organized.***

As noted in the Results, one of the first observations from the initial read-through of the discussion forums was that each PBL case started with an organizational meeting for both distance and blended teams. The distance team meetings could be explicitly observed as a collection of organization posts, usually occurring early in the case forum. When the content of these messages was read, the posts related to topics like determining who would moderate, what the initial approach should be, dividing up the work, establishing internal deadlines and identifying initial information gaps. The blended team meetings were never observed online, but the forum often contained evidence of them in the form of reminders of meeting times and locations for face-to-face meetings, or minutes of the meeting being posted after the fact. For some blended teams there was no evidence on the forum that they met at all, but interviews confirmed that blended teams had an initial face-to-face meeting to get organized. Bob described this process as the team “getting a handle on the scope [of the project]”. Bev described the purpose of meeting as

...clarification, and going over how we approach questions and answers, methods, and then you know, delegating....the group would come together and they would basically delegate subgroups and those subgroups would have a focal area.

Bob added that “very little actual work [research] was being done during those meetings. Yeah it was getting to the work and managing and getting the work done. But the work itself was done quite individually.” When Bev thought about how her team set their internal deadlines, she said the group was “looking at calendars, aligning it with

other deadlines in other courses, deadlines in this class, and then probably sort of establishing what sort of timeframe you're looking at." Bob agreed that his team also used a similar method:

It was a discussion on what...Like so we had the week and we had something that had to be accomplished in the week and what pieces needed to come first. So therefore working what was respectable, was that a day or two? Was that an hour or two? So there was a group discussion around the realistic timelines. So we'll be done in 2 weeks and what can be realistically accomplished. (Bob, 2010 blended student interview)

This implied that the internal deadlines were negotiated in the team rather than being imposed by the student moderator, something that was not obvious from the discussion forum posts.

One major difference in the use of meetings by the distance and blended teams was the issue of time. For distance teams, the observed meetings were largely asynchronous and may have required a few days before everyone weighed in and a decision was reached, especially if the team members were in different time zones or had different work schedules. This was a problem if a rapid decision was needed to move forward on something. Distance cohort interviewees mentioned that some groups circumvented this problem by having off-forum meetings using Skype, MSN messenger, telephone or other synchronous technologies when timing was more pressing. There was also evidence on the forum of this occurring because contact information was exchanged on the forum, as well as some posts referred to offline conversations. In contrast, blended teams met face-to-face, and were able to come to decisions and delegate more quickly than their distance counterparts. Whether these faster decisions were advantageous beyond the ability to make them quickly is uncertain. For instance, it is possible that with more time to consider factors such as outside obligations, that there might be fewer conflicts within distance teams regarding failures to meet internal team deadlines, although this topic did not come up in the interviews.

It was noted that the subgroups that were established during PBL case one were always carried through the remainder of the PBL cases. These two or three member subgroups were self-selected within the team. Each interviewee mentioned having "go

to” people that they usually went to for discussions to clarify ideas and approaches. In the discussion forums, the individuals mentioned as “go to” people seemed to be part of the same subgroups as the interviewee.

### ***Organic versus use of organizational scaffolds.***

When teams use the organic discussion style, threads are started on an “as needed” basis by the message author. For blended teams, this often resulted in very short threads because students started a new thread each time they posted a message and very little if any discussion occurred. This behaviour reflected the comments of Bob who referred to the discussion forums for his team as “an ideas repository” (Bob, 2010 blended student) that was meant to allow the moderator to collect the team’s ideas for incorporation into the final report. Distance teams that used the organic format had the longer threads and discussion of ideas with teammates that would be expected when the discussion forum is the primary means of communication.

The second discussion style uses organizational scaffolds to provide structure to the discussion by grouping related messages. In this discussion style, one member of the group, usually the student moderator, made a series of posts to the forum to organize the discussion before the other team members began posting. As noted in the results, each PBL case problem contained certain elements that were required to be addressed in the case report. These hard scaffolds were meant to provide students with some guidance in identifying knowledge gaps and learning opportunities/issues. This is another example of an instructional design element that was used intuitively by the instructor based on personal experience but was later supported by the literature as a means to guide students by providing cues or prompts to help students to determine scope of the problem (e.g. Jonassen, 2000). Hard scaffolds also support students’ confidence in their ability to solve the problem (Jonassen, 2000) by reducing the ill-structured nature of the problem to a more manageable level. This confidence is especially important in the first two case problems because students are still learning how to be successful in PBL and in the course overall. The use of hard scaffolds was related to the use of organizational scaffolds discussion style because the student moderator used the text of the hard scaffolds provided in the PBL case problem as the

header for organizational posts that typically did not contain any text in the body of the post. This behaviour was very easily identified in the thread maps as a series of organization messages posted at the beginning of the discussion period by a single author within five minutes of each other. In teams that used this discussion style, other team members did not start threads; they only posted replies to the organization messages posted by the moderator. It was also common for a thread to only be posted to by certain individuals in the team – that is, threads were used by particular subgroups. In distance teams, there was often discussion within these subgroup threads, but discussion within the forum threads was not always present in blended teams. One variation of the organizational scaffolds discussion that was occasionally observed had each subgroup using the hard scaffolds from the PBL case problems to start the threads that they needed rather than the overall team moderator. These subgroup-generated organization threads appeared a little later in the discussion than would have been expected for team moderator set up threads, but otherwise, these discussions proceeded in the same way as the other discussions that used organizational scaffolds.

When asked about how the team decided whether to use an organic or organizational scaffold method for their online discussion, all four interviewees indicated that this was a decision by the moderator rather than the team. In one case, the interviewee commented that their team had a dominant personality that moderated the first case study, and set up the discussion using organizational scaffolds. She then continued to set up the organizational scaffolds regardless of who was moderating for the other three cases, and because she was good at organizing and keeping the team on track, her teammates didn't contest her assuming this role.

Distance teams were more likely to use the organizational scaffolds approach to their discussions than the blended teams (65% versus 46% respectively). This may be a reflection of the distance students' relative experience or their greater number of posts overall requiring more organization. The use of organizational scaffolds would seem to have made the assembly of the final report by the moderator more straightforward by collecting related information into single threads. This will be revisited in the section on document assembly. Most teams used one approach or the other consistently across all

four case problem discussions. For teams that changed their approach, there didn't seem to be a pattern to the change – as noted in the results, the teams may have started with an organic approach, and moved to an organizational scaffold approach or vice versa or alternated between the approaches. Although the pool of interviewees was small with only two participants for each of the distance and blended 2010 cohorts, this observation seemed to agree with their statements that the discussion approach was driven by moderator choice or a dominant personality within the team rather than being a team decision. The consistency of approach will be revisited in chapter six.

### ***Building on their own ideas.***

There were examples of threads in which it appeared that a student used the discussion forum as a note-taking area. They started a thread with an exploration message that contained paraphrased material from a single source, and continued adding exploration messages to the thread over the course of several hours. These threads sometimes culminated in a final integration post that brought the ideas from the earlier exploration posts together. There were several possible explanations for this behaviour. For example, the forum was a convenient place to store these informational notes, possibly because the student was not working on their own computer. This behaviour may also have been driven by the course requirement to post at least twice per week, or some other unknown factor. Unfortunately it was not possible for the investigator to clarify why the students did this because none of the interview participants exhibited this behaviour.

### ***Undocumented resolution.***

Although this study was focused on online communication in the form of asynchronous online discussion forums, it was important not to lose sight of the fact that offline communications were still occurring for both distance and blended students. As a result of this offline activity, the discussion forums showed evidence of “undocumented resolution” or instances where the discussion forum did not show all the communication that was occurring between team members. Some examples of undocumented resolution were: key questions that were asked but not answered on the forum; information that was not posted to the discussion forum but was included in the team

PBL case report; and documents that were not assembled on the discussion forum but were handed in. Interviews with blended students confirmed that they frequently met with their team offline and that they felt that those discussions were critical to their understanding of the course content and PBL cases. Blended teams often assembled their final documents off of the forum, and did not necessarily post the final document to the forum at all. It was not unusual for moderators to simply add their own research directly to the document they were assembling rather than posting their research to the forum first. This was especially common prior to 2009, when the penalty for not posting in the discussion forum was made explicit. With regard to questions that were asked on the site not being answered on the site, one of the interviewees (Bob, 2010 blended student) indicated that those questions may or may not have been addressed at all. If they were critical to the understanding of something, they may have been addressed offline whereas if they were not, then they may have been left unanswered. In some instances the questions may have been asked to draw attention to an issue that needed to be addressed with offline discussion.

### ***Methods of document assembly.***

This requirement to submit a team report that summarized the discussion and the team's solution for each PBL case appears to have had the desired effect of encouraging teams to reach a resolution of the case as there were no instances in any of the cohorts of this study in which a team failed to hand in a case problem report.

Dean, a distance 2010 student commented that

...by having to have the final document, that kind of, it gave you more of a feeling that there was something that you had to do, the whole effort had to be more...it had to have a bit of polish to it I suppose. You know, sort of, gave you a sense you needed to be a little careful as to how you finish things up, make them complete, I suppose.

It should be noted that for the blended teams, it was not unusual to see no evidence of document assembly on the forum at all (see Undocumented Resolution). There were a few different methods of document assembly that were used by both the distance and blended teams: end point assembly, sectional assembly, or template-based assembly.

Some teams assembled their document entirely at the end of the posting process. These teams established an internal deadline for the addition of information to the forum, and then the student moderators for that case problem assembled a draft that they circulated to the rest of the team for comments and corrections. All four interviewees indicated that internal deadlines and timelines were negotiated within their group rather than being set solely by the moderator. If a draft report appeared on the forum, it was usually first observed two to three days before the report was due to the instructor. The appearance of the draft initiated a round of integration posts as the content of the draft was edited and corrected. No observable assembly occurred prior to this point, although individuals may have integrated information from several sources into their posts. There was no observable relationship between the use of this type of assembly and whether the team used organic or organizational scaffolds as their group approach to the discussion forum. Although the possibility exists that some moderators may have been assembling the document as the discussion proceeded, the investigator found no reference to this on the discussion forum, and it was not mentioned by any of the interviewees.

Sectional assembly was used by some teams in combination with the use of the organizational scaffolds approach to the discussion forum. In this situation, several individuals contributed information as replies to the organizational scaffold post in order to build up a summary post by either the overall team moderator or one of the members of the small group assigned to that thread, in a format that is suitable for inclusion in the team report. These summary posts include properly formatted and cited reference material, and integrate the content from the other posts within that thread. The moderator then assembled these summary posts into the final report for that PBL case problem, which was circulated to the team for comments and corrections. Sectional assembly was easily identified on the discussion forum when it was in use. The subgroups that were responsible for the individual threads were usually established during PBL case one and carried through for the rest of the course. When asked about the process involved in the subgroups as compared to the larger team, Bob (2010 blended learner) commented that “it was much more linear in our small groups. It was much more collaborative in how we did it, and we would put our pieces together and

work with it.” He further commented that while in his experience the smaller subgroups really spent time refining and polishing their summary posts, the subgroup as a whole was less likely to be involved in polishing the final product, as they had already handed off their “finished” product.

For teams that used template-based assembly, a template was generated for either a section of the final document or the final document as a whole that was used by everyone. Template-based assembly had the advantage of ensuring a consistent format for the information provided to the discussion forum and appeared to make it easier to assemble the final document as the level of detail and formatting were agreed to in advance. Once the template was populated with the appropriate information, it was either integrated into the report or became the final report, depending on how extensive the template was.

The method of document assembly that was chosen seems to have been driven by the choice of the moderator(s) for PBL case one and was almost always carried on through the rest of the cases. Don indicated that being the moderator was “your opportunity to do things the way you wanted them done.” Once the initial draft had been prepared, a round of edits, comments, and corrections was initiated. Editing order within the larger team was determined by a variety of different factors including: the existence of a pre-arranged group and order of editors; member availability; editorial proficiency; or a dominant personality that felt they had to be involved in editing.

***On- versus off-forum document assembly and impact of collaborative writing tools.***

All distance and blended teams submitted all four of the required PBL case reports but distance and blended teams differed with respect to the location of assembly. The majority of the distance team reports (91.7%) were assembled on the forum, with the remainder being assembled on Google Docs or a similar collaborative writing platform. As the distance teams do not have the same opportunities to do collaborative work like document assembly face-to-face, it is expected that the use of collaborative writing tools and synchronous audio chats will increase in the future as students become more familiar with them. By contrast, only 18.4% of blended team

reports were assembled on the discussion forum. The two interviews with members of the 2010 blended cohort indicated that document assembly was usually done face-to-face, often with a group assembled around a single computer.

Collaborative writing tools such as Google Docs are useful for team projects because team members can work on the document simultaneously, and there is no possibility that someone is working on the “wrong” version of the document. Challenges can include the learning curve associated with such tools for team members who are less technically proficient, and an inability for instructors to observe the student contributions if they are not invited to the shared document. In future it is likely that collaborative writing tools will be used more frequently by both distance and blended teams, although some blended teams may still prefer to do editing face-to-face.

The use of Upstartle’s Writerly and Google Docs were not heavy influences on this particular study as most teams either did not have access to or elect to use them. Writerly was released in 2005 as a web-based word processor. Upstartle was purchased by Google in 2006, and later that same year, Writerly was combined with Google Spreadsheets to form Google Docs. Google Docs was released from beta-testing in 2007 and became widely available to the general public (Google Docs, Sheets and Slides, 2017). Although the use of such tools has not heavily impacted this study, with only two teams (a 2006 distance team used Writerly for 2 case problems and a 2010 distance team used Google Docs for 3 case problems), electing to use these tools, future studies of online discussion forums will need to take their use into account. In the five instances where a team used either Writerly or Google Docs, their online approach/behaviour was different in the discussion forum than for the case problems in which the collaborative writing tools were not used.

When Writerly or Google Docs was in use, teams posted more organization messages and fewer messages with critical thinking indicators (exploration, integration or resolution posts) per case problem than teams that used the discussion forum as their primary means of communication because the evidence of these activities occurred directly on the collaborative document. As a result, most of the organization posts on the discussion are directional pointers to the collaborative document (e.g. “I have posted the list of contaminants to the Google Doc”). The team members were still

required to post to the discussion forum, and the use of the directional posts may have been driven both by this requirement as well as served to highlight to the team what changes had been made to the collaborative document. If the use of Google Docs becomes widespread within both distance and blended cohorts in the future, participation in the discussion forums may need to be replaced by participation in the Google Doc to keep the assessment relevant. As only one of the interviewees (Don, 2010 distance student) was on a team that used Google Docs, it wasn't possible to generalize the rationale behind the use of the organizational posts – he felt that it was a way to draw attention to the tasks that had been completed, but wasn't sure if there were other reasons underlying this behaviour.

Although some student moderators did provide the instructor with a link to observe the team's collaborative off-forum writing, this was not always the case, and did cause difficulties for one team, which will be discussed further below.

Don's interview provided insight into the team process that was interesting because his team used Google Docs for case problem one, three and four, but not for case problem two. When asked if the use of Google Docs was a team decision or a decision made by the moderator for case problem one and what the reasoning for the choice was, Don commented

We were all pretty new to Google Docs and I remember talking about it. With these group assignments you're always passing stuff back and forth and if somebody already has it signed out, nobody else can have it. So at least this way it was our way away from that. Everybody had access to it, so if 2 people wanted to work on it at seven at night that's fine. Whereas, most assignments to that point whoever's going to have it from 6-8, that's fine, but with other groups you wouldn't get the assignment back or somebody would make edits and they wouldn't have signed it back in. You would've taken it and made your edits and things wouldn't have gotten done. I think that's why we were really keen to use Google docs. (Don 2010 Distance student interview)

The discussion forum posts had indications that not everyone on the team was familiar with Google Docs or how to set up the collaborative documents within it. Don confirmed that he had some previous experience using it prior to the Ecotoxicology

course and he didn't believe the learning curve was too large. He also indicated that there were team members who assisted those who were having technical difficulties with the tool (Don, 2010 Distance student interview).

For the first case the team that Don was on used Google Docs but the moderator did not provide a link to the document to allow the instructor to observe it, and a major error of omission was discovered when the PBL case report was submitted. Don suggested that this may have been due to a team member taking on part of the assignment and then not following through on it without the moderators noticing. This error of omission made the team a bit skittish about the instructor not seeing their online work, and resulted in the team using the discussion forum as the sole means of communication and document assembly for case problem two. Interestingly, a thread arose near the end of case problem two discussing the problem of all team members contributing to the assembly of the case problem report, and the need to return to the use of Google Docs for document assembly and editing. The team returned to the use of Google Docs for cases three and four, but the moderators extended an invitation to the instructor to observe the collaborative document.

Although the behaviour of the teams that used Google Docs is quite different from the other distance teams that used the forum as a site to assemble their final case problem reports, the investigator decided not to eliminate those teams from the study. Although it makes the distance team's results a bit more variable, it is a better reflection of the differences that occurred in the team approaches to the online PBL exercise when comparing to the blended groups in this study. In this study the use of Google Docs was a difference in approach between the distance and blended teams because there were no instances of blended teams using Google Docs for document assembly. It was also only used by 8.3% of distance teams so eliminating these teams from the data set would not change the conclusion that the vast majority of distance teams assembled their documents on the forum. The 2014 distance cohort and the 2016 blended cohort both had more than half of the teams using Google Docs for document assembly. Therefore, going forward the marks assigned to participation will need to be flexibly assigned to either participation in the Google Doc or the discussion forum on a team-by-team basis. In future, the choice to use collaborative writing tools is likely to

become more popular due to the flexibility in document assembly and editing that they offer, so it is useful to be able to make comparisons to this baseline when the use of such tools was not yet as widespread as it may become.

***Document assembly - use of sign outs.***

While the use of Google Docs (distance teams) and face-to-face assembly (blended teams) are two possible ways of assembling and editing the case problem reports that allow multiple individuals to work on them simultaneously, most distance teams in this study (91.7%) used the forum as the primary site of document assembly. Identifying which version of the document is the most current and being sure that only one individual at a time is working on the main draft of the case problem report are two challenges associated with assembling the document on the forum. This problem was commonly overcome by the moderator starting a new thread with the initial draft of the case problem report (usually called “Draft” or something similar), and the team agreeing to use a sign-out procedure. This is a common solution that student moderators arrive at without instructor input. This involved students posting a message stating they were signing-out the document and an approximate time that they would be returning it. The student then returned the altered document by posting it as a reply to their “sign-out” post. Students often included text in the body of the post that indicated what changes were made to the draft, and sometimes also indicated what remained to be done. The combination of a dedicated thread for document draft assembly and a sign-out procedure was an effective tactic for ensuring that the most recent draft could be recognized. This was particularly important as teams rarely used version numbers to distinguish the various drafts. In the more recent distance and blended cohorts, the instructor does share some of these ‘best practices’ that have been used by past teams to help scaffold team organization.

The use of the sign-out procedure was also helpful in identifying which team members were participating in the assembly of the case problem report. Observations of the discussion forum threads indicated that for most teams the same set of individuals participated in the assembly and editing of the draft reports regardless of which team member posted the initial draft. Interviews indicated that editors were

determined by editing proficiency, dominant personalities, availability (often determined by a team member's time zone), or a combination of these characteristics, leading to the formation of a defined editing order that was maintained across all four cases.

In some teams, the assembly of the case problem report proved to be a source of conflict due to individuals not contributing as much as others felt they should. Bob (2010 blended student interview) pointed out that common sources of conflict that arose were

... those that took control when they weren't in the moderating role. And those that would step into the editing process when it wasn't their turn to edit and have to have final say. Trust issues around work quality and that kind of thing.

Although conflict definitely arose in the blended teams as shown by Bob's comment, team conflicts weren't obvious from their online posts. This is most likely because the blended students had the opportunity to meet face-to-face, and therefore, likely expressed any issues they were having with one another and resolved them in person. If the team was unable to fully resolve whatever the problem is, they were usually able to at least find a way to work around it.

For distance teams, however, conflict that occurred in the online forum seems to have the added impacts of being in print and drawing everyone's attention for an extended period as authors can only remove posts within the first 30 minutes. Although it doesn't occur frequently on the forum, there were a couple of examples of conflict threads. The reasons for conflicts in distance teams appeared to be the same ones that were mentioned by Bob that occur in the blended teams— uneven effort, trust and control issues. In one example, a thread contained responses to someone posting a "rant" in the Writerly document they were using. The person who started the conflict by posting the rant seemed unrepentant, and several others tried to step in to cool things off. The conflict lasted more than a week and produced enough hard feelings for one participant to have requested a transfer to another team. In this situation, it seemed like conflict was greatly prolonged by being in print.

***Interaction with time.***

Time was a consideration for the asynchronous PBL case discussion forums in several different but interacting ways. The discussion forums were asynchronous because the instructor felt that time was required to reflect on new knowledge and incorporate it into the student's thought processes. Although teams could achieve a quasi-synchronicity by arranging to be logged into the discussion forum at the same time, the Moodle platform holds the post for 30 minutes after the writer uploads it before it is visible on the forum, preventing synchronous communication. The expanded time that results from asynchronicity also provides an opportunity for students to research and revise before committing their thoughts to the team (Meyer, 2003; Tiene, 2000) in a way that synchronous discussions, including face-to-face discussions, cannot duplicate. One disadvantage of the time involved for asynchronicity is that it takes longer to come to a decision. For example, the straightforward question "who is going to moderate this discussion?" is a common decision that the team must make prior to starting content driven research or delegating work. For distance teams, it may require up to two to three days for everyone to weigh in on the decision, whereas for blended teams, this is a decision that is made within minutes at the initial group meeting.

Time also entered into the discussions in other ways. Teams that used organizational scaffolds contained at least one member that was active very early in the process as these scaffolds were the first posts to the discussion forums. It was not uncommon for several days to pass before reply messages to these organizational scaffold posts began to appear. Similarly, if a team used template-based assembly, the templates appeared early in the discussion forum. This made logical sense because the purpose of a template was to have all team members submitting similar content in an identical format to allow for easier assembly of the final report. Document assembly occurred later in the process with editing often continuing right up until deadline for some teams.

Time was a negotiated quality in the teams – internal deadlines were negotiated with respect to the amount of time a particular task required, how long document assembly and editing were anticipated to require, and what other deadlines and deliverables were looming for the team as well as individual group members.

### **Content Analysis.**

Two coding schemes were developed; one for collaborative behaviours and the other for student learning scaffolds. The social interactions of the teams were categorized using the social presence indicators (affective communication, open communication and cohesion) from the Cofl model as described by Garrison et al. (2001) because they were already part of the Cofl model and had been validated (Arbaugh, 2007). The online discussion posts were analyzed for their content, focusing on evidence of students working together (collaboration), supports for their learning (learning scaffolds), and social interactions. The following sections describe the development of the two secondary coding schemes for collaboration and learning scaffolds (CLS), as well as the application of the Cofl social indicators coding scheme to the online discussion posts.

#### ***Collaboration and learning scaffolds (CLS) coding schemes.***

Although the Cofl cognitive indicators were useful for examining the research questions that focused on the critical thinking that was observable in the discussion posts, there were still many unanswered questions about how the groups were approaching the online PBL cases, and what learning scaffolds they were using. Reading through the discussion posts suggested that both distance and blended student posts contained evidence that students were working together, that they were using various resources beyond the course's required textbook and the databases that had been recommended for their use, and that they were interacting socially. Posts that contained evidence of collaboration, learning scaffold use and social interactions seemed to occur more frequently in the discussions of the distance teams as compared to the blended teams. Many behaviours and approaches that were explicitly observable in the discussion forums for the distance teams were invisible in the blended team discussions, and may or may not have been mirrored offline. As the cognitive presence indicators that had been used to address some aspects of critical thinking in the research questions were not helpful in assessing questions of how the groups were working together or what scaffolds they might be using, the investigator looked for

evidence of collaborative behaviours and what learning scaffolds were used that might be used to address these behaviours.

Further investigation of these observations required the development of coding schemes separate from the Cofl model for collaboration and learning scaffold use. An open coding process was used to create a list of collaborative behaviours and sources that represented examples of learning scaffolding. The learning scaffolds fell into two categories: scaffolds that were represented by guiding questions within each case, or reading materials that had been specifically assigned for each case such as textbook readings, recommended databases or lecture notes; and scaffolds that were represented by student generated or shared materials such as action plans, sign-up sheets, templates, work experience or source materials that they found themselves. The following sections will describe the evolution of the collaboration and learning scaffold (CLS) indicators, and the pilot coding process.

*Development of the CLS coding scheme.*

At first all potential behaviours and source materials were added to a single list, regardless of how related they were to one another. After several iterations of this list, the investigator realized that the list could be condensed and re-organized into two coding schemes – evidence of collaborative work/working together; and learning scaffolds. The ‘evidence of collaborative work’ coding scheme allowed the capture of a number of different behaviours that have to do with group communication, organization and document assembly. This coding scheme also aligns with the RRU learning and teaching model (LTM) which emphasizes collaborative work as a key element of adult learning (Royal Roads University, 2013b). It was decided to separate the collaborative behaviours coding scheme from the learning scaffolds coding scheme to more easily apply them to the research questions. The observations that lead to the final behavioural indicators of the social, collaboration, and learning scaffold coding structures will be discussed next.

Cofl social presence indicators.

One of the first impressions of the distance discussion forums was that the indicators for social presence in the Cofl model might be useful, as it had been

observed that some posts included salutations, or jokes, or other purely social interactions like comments on the hockey playoffs. While these behaviours did not provide course related content, they did allow students to show some “personality” in their posts and interact in a social way with one another. This is the online equivalent of the small talk that occurs in face-to-face classrooms before and after class, and is important in reinforcing the social relationships between team members that also support their learning (Garrison & Arbaugh, 2007; Guilar & Loring, 2008).

#### Development of the collaboration coding scheme.

Various behaviours in the discussion forums were noticed that could be used to indicate that students were collaborating. The final list of collaboration indicators and behavioural examples is found in Table 23. The following section will discuss the how the investigator’s observations developed into the various collaboration indicators.

At one point, the investigator considered adding an indicator to the collaborative coding scheme for postings that were related to assignments that the group was working on for other courses that didn’t include a discussion area in their course site because it spoke somewhat to their group processes. This idea was quickly discarded as there were relatively few instances of this and the processes didn’t look appreciably different from those used for the PBL case discussions that the study was focused on. These posts were not included in the coding for the collaborative indicators and were discarded from the coding for the Cofl cognitive presence indicators.

A series of posts by distance students showed the need for an indicator to capture discussions of student availability; that is, when they are planning to be online, whether they are going to be travelling for work, if they are going to be online on the weekend, etc. This category was added to the collaboration coding scheme because communicating with your team and letting them know when to expect your communication is necessary for collaboration. These posts were much more common for distance students because the forum was their primary means of communication. While these same ideas were likely to be communicated among blended students, it was likely to occur face-to-face in a team meeting or just in casual conversation before or after class.

In the first list of potential collaborative behaviours, the investigator was not sure if posts that contained telephone numbers would be treated separately from posts that included MSN or Skype user names or not. It was noticed that these posts also included a date and time to “meet” offline. As a result, these behaviours eventually became grouped as the meeting organizers indicator, and this indicator also included reminders of date, time and place for blended face-to-face meetings, and telephone meetings.

The meeting notes indicator captured notes or minutes from in-person, Skype, MSN, or telephone meetings. The choice of the medium for meetings depended on what the team members had available, what their primary mode of communication was, and what the purpose of the meeting was. Meeting notes were more likely to be lists of action items with individuals assigned rather than providing details of the discussions as might be expected for meeting minutes. For example, there was no evidence in the discussion forums of approaches or ideas that were discussed but that the team decided not to pursue. This was interesting as testing ideas is part of the PBL process and some ideas are not going to pass the criteria that the team is using for continuing to follow-up on the ideas. It was because of this that the behaviour indicator was named meeting notes rather than minutes, which would have implied more detailed notes including reasoning false starts. No examples were observed of minutes being provided for offline meetings whose purpose was to clarify ideas or ask questions of the smaller subgroups within the team. When detailed meeting minutes were provided in a post, it was usually for the initial meeting at the start of a PBL case where the objective was to establish the scope, approach and division of labour for the problem.

There was only one distance team that posted a copy of their MSN logs to the discussion forum so that it could be observed by the instructor. It is not known how frequently other teams may have used MSN, and none of the interviewees were able to comment on the use of logs because their teams didn't use it to any great extent. The investigator decided to carefully look at the content of logs because although it definitely seemed to be evidence of collaborative work, it could also have been considered building on each other's ideas or brainstorming – two other potential categories that appeared on the first list of collaborative behaviours. Eventually, it was decided to code

any MSN or Skype logs to the meeting notes indicator as they were products of the meeting rather than requests for a meeting.

Another possible behaviour added to the list of collaboration indicators was for students recommending references that they had found to each other. Such posts often began with statements like “This is a great website for...”. Initially it was uncertain if this category should be subdivided by the types of reference material that were being recommended. Later it was decided that splitting posts that included this behaviour into several indicators would not be useful because the collaborative behaviour is recommending the reference regardless of what kind of reference material it is. These posts were sometimes a response to requests for help by other individuals, but usually appeared to be unsolicited. It is possible that some of the seemingly unsolicited posts were actually responses to offline requests but it is unknown if this was the case as none of the interviewees were responsible for this type of post.

Signing up for research topics was added to the list of possible collaboration indicators when it was noticed that sign-up sheets for topics were being posted, usually by the student moderator in an effort to divide up the work. These sign-up sheets consisted of the topic list with the addition of the student’s name beside the topic of interest. As the students reply to the most recent post, the topics are gradually filled and a thread forms under the moderator’s post. These sign-up posts usually don’t contain any other text except for the list. The two potential indicators, signing up for research topics and agreement with plan/disagree with plan, were combined because in many instances the moderator directly asked someone to take on a task. It wasn’t really the person signing up to do so, but it fulfilled the same role of assigning work to individuals. Sign-up sheets were usually posted by the student moderator, but there were also examples of them being posted by dominant personalities or members of the small subgroups within the team.

Feedback on previous cases was considered as a potential collaboration indicator. This behaviour was observed when the moderator of the previous case provided feedback to the group on what worked or didn’t work for them. While relatively few distance groups did this online where it could be observed, it seemed to help the group process run more smoothly as the student moderators and the rest of the team

were able to more explicitly learn from their past experiences. Interviews indicated that feedback was often shared offline, and so was not visible in the discussion forum. Providing feedback was rolled into the moderator indicator when the final list of indicators and behavioural examples was drafted as this role seemed to fall only to the moderator of the finished case.

Moderation was a collaboration indicator that initially included posts made by the designated student moderators to organize and encourage the rest of the team. Although it is usually the designated moderators whose posts fit into this indicator, sometimes other students also have posts that fit this indicator. As a result, the moderation indicator had to be expanded to capture such posts. The final version of the moderator indicator captured behaviours such as suggesting an approach or action plan; requesting for information to fill gaps; pushing for more discussion; posting of templates/outlines/ or discussion set up; and providing feedback post-case.

Messages posted on behalf of a pair of students or small subgroup became a collaboration indicator known as multi-author messages (see Table 23). Interestingly it is also an example of a behaviour that was observed in both distance and blended teams to an approximately equal degree (means of 0.52 and 0.64 posts per case for distance and blended teams, respectively).

#### Development of the learning scaffolds (LS) coding scheme.

The generation of the LS coding scheme was generally more straightforward than the development of the collaboration coding scheme. Table 25 shows the final list of the LS indicators. The LS indicators for the different kinds of reference citations (e.g. textbooks, websites, etc.), were finalized very quickly and will not be further elaborated on this section. Unlike the sharing references indicator of the collaboration indicators, for the LS indicators, it was important to have different types of citations separated to examine whether or not distance and blended teams were using different types of reference materials. This section discusses the development of the instructor related LS indicators.

Interactions between the students and the instructor were initially looked at with a view to using the already established teaching presence categories from the Cofl model. Teaching presence has three indicators: design and organization; facilitating

discourse; and direct instruction (Garrison et al., 2001; Garrison & Arbaugh, 2007). Of these three indicators only direct instruction was applicable because the design and organization category applies to the overall course and activity design; and the facilitating discourse category was a role delegated to student moderators in this activity. The direct instruction indicator seemed too broad, so an open coding approach was used to look for other potential indicators that could be used to further characterize the instructor's interaction with the students.

Instructor responses to student questions were added as a potential LS indicator, but the investigator noticed that this indicator did not capture some other forms of instructor interaction with the students that supported student learning. For example, the re-posting instructor information indicator represents posts in which a student posts information that they gathered either by emailing or meeting privately with the instructor (see Table 25). In addition, there were also examples of the instructor intervening to correct a misconception or offer advice without students specifically requesting it. It was later decided to use the Instructor posts indicator to capture direct interactions, and reposting instructor information indicator to capture indirect interactions with students (see Table 25).

#### *Pilot test of CLS indicator codes*

A pilot test was conducted with a first draft of the Collaboration and Learning Scaffolds (CLS) indicator codes using a single case discussion forum for a single team (Team one, Case one from the 2006 blended cohort). This discussion was coded in a couple of different ways. The first time, used a very early version of the CLS indicators that included using moderator as a category to capture anything that seemed to pertain to moderator or organizational moves. This version of the moderator category seemed to capture too many things that weren't necessarily related, and showed that this indicator needed to be refined. A second trial was attempted trying to integrate the use of the Cofl cognitive indicators and the new CLS indicators. This pilot test highlighted a problem. A single post could be easily assigned to one of the mutually exclusive Cofl categories resulting in a reasonably sized data set that could be compared to other studies (e.g. Garrison et al., 2001; Meyer, 2003). However, the indicator categories for

the CLS and Cofl social presence indicators were not mutually exclusive; and as a result a single post could contain multiple examples of collaboration or learning scaffolds (CLS indicators) and multiple examples of social behaviours (Cofl social presence indicators). For example, a post may contain a textbook citation, as well as two other citations to websites that the student found. Coding the post to the textbook citation node did not preclude the post also being coded for the website citations.

The pilot test indicated that simply enumerating the number of posts that contained at least one CLS indicator was not sufficient to address the research questions about the distance and blended teams' online PBL activities. In addition, trying to combine the coding of the CLS indicators with the Cofl cognitive indicators was too difficult to do and interpret. As a result, a decision was made to use the Cofl cognitive indicators, social indicators and the CLS indicators separately to address the various research questions. As a result of these observations, smaller units of analysis (i.e. words, sentence fragments and sentences) were used for the CLS and Cofl social coding schemes. The sections below outline a comparison of their use by distance and blended teams in the online PBL case discussions. A complete list of the final versions of the CLS indicators and their behavioural indicators can be found in Table 23 and 25 in the results section.

#### *Collaboration indicators.*

The final list of collaboration indicators is shown in Table 23 in the results chapter with the behavioural examples for each indicator. These indicators were applied to the discussion forums for all teams. This section will discuss the correlations that were found between the various collaboration indicators as well as compare their use between distance and blended teams.

A series of bivariate Pearson correlations were run to determine if the collaborative indicators varied with one another when the distance and blended cohorts were combined (see Table B9 in Appendix B). Because the indicators were based on behaviours that were selected as examples of collaborative behaviours, it was expected that correlations might exist between the various collaborative indicators. In agreement with those expectations, a strong or moderate correlation was observed between most

pairings ( $p < 0.05$ ). The meeting notes indicator and the multi-author messages indicator were exceptions to this observation as they did not significantly correlate with most other indicators or with each other, but they each individually correlated with the meeting organizers indicator (see Table B9). The meeting notes and multi-author messages indicators were also the least frequently observed indicators, with less than one occurrence each per team discussion for both distance and blended students (see Table 24). These two indicators were also the only indicators that did not show a significantly larger number ( $p < 0.05$ ) of posts per case for distance teams versus blended teams in independent samples  $t$ -tests (see Table 24 and Table B10 in Appendix B). This is another example of how the online PBL case discussions of the distance teams show a more complete picture of what the team is doing because the discussion forums are their primary means of communication. This doesn't mean that there isn't communication occurring off the forum, as interviews and observations of the forum (e.g. exchange of contact information) confirm that it is, but rather that more of it is on the forum than is the case for blended students. Many of the behaviours documented by these indicators would be either part of a scheduled face-to-face meeting or part of small talk exchanged before and after class for blended students.

The two examples of collaborative behaviour that are used most frequently by blended students are the moderator and use of templates indicators; although they are still not used as frequently as they are by distance students (see Table 24). Moderator comments per case are still approximately six-fold higher for distance teams than for blended teams, likely reflecting the difference in the location of document assembly with 91.4% of distance team reports being assembled on the forum versus only 18.7% of blended team reports, and the greater number of moderator interactions that are involved in assembling the report. The aspects of the moderator role such as encouraging the online discussion or requesting information are observed online in blended team discussions, especially as deadlines are approached. Other aspects of the moderator role such as suggesting an approach, or providing feedback after the case may be aspects of a face-to-face meeting, and thus observed less frequently in online discussions by blended teams. Moderators who take a more visible role in the discussion forum may be doing so either because this is a reflection of their personal

leadership style but it is also possible that some moderators are also attempting to draw the instructor's attention to their activities by posting more often.

It is not surprising that there are few instances of the use of availability/timeline, informing the team or topic sign-up/plan agreement indicators in blended team online discussions. These indicators capture information that is likely to be part of a face-to-face meeting or casual conversation between team mates for blended students, whereas distance students need the discussion forum to act as the information repository for this information.

Another difference between the groups that is highlighted by Table 24 in the results section is the large discrepancy between the distance and blended teams in terms of asking and answering each other's questions on the discussion forum. The greater asking and answering questions by distance teams as compared to blended teams highlights the use of the discussion forum as the primary means of communication for the team. It also demonstrates why the investigator had the impression that distance teams were actually exchanging ideas rather than just using the discussion forum as an information collection point. It must be emphasized again that the content analysis only captures what was happening on the discussion forum – it does not mean that questions weren't being asked and answered by blended teams, only that these exchanges were occurring off of the forum. Both students who were interviewed from the blended teams emphasized that face-to-face discussions were critical to their understanding of the course materials. The exchanges of questions and answers could occur more rapidly face-to-face but without the permanent record of the exchange provided in the online discussion. This may also decrease the feeling of vulnerability by students by being able to get assistance without the entire team being privy to it.

The role for the moderator that was observed in the discussion forums goes beyond just setting up threads for teams that used organizational scaffolds. Don (2010 distance learner) commented:

As long as you run it, and you had time to do the course properly and then this is your time to sort of shine and say this is what we're supposed to be doing. And

try to take some advice from everybody that was involved. But for the main part, you just let people know how you want it done.

Don's comment highlights that the moderator role is an opportunity for students to assume a leadership role in the team for that particular PBL case. The student moderator usually suggested the approach to the team as well as how the work might be divided up. In the distance teams interviews indicated that this was usually a fairly unilateral decision, with the moderator posting a topic sign up or starting threads and requesting team members to volunteer for topics by a certain deadline. In the blended teams, the face-to-face meeting that kicked off each case study was more likely to make the overall approach/scope determination a bit more collaborative, although this process could have been dominated by team members with strong personalities. There were a couple of instances observed of distance teams in which a moderator suggested an approach, and it was adjusted after the group started but that seemed to be because either the work was not as evenly distributed as it initially seemed or because individuals were not available/able to fulfill the work they had committed to by an internal deadline.

Teams needed the moderator to be actively engaged in either assigning research topics or providing direction to sign-up for topics by a specific deadline rather than just hoping everyone will contribute to each topic. It was observed that in the few instances where the moderator did not do so, that the team had very few posts for most of the time over which the discussion was supposed to occur, followed by a flurry of posts in the final weekend before the team report was due. Examples of this behaviour were observed in both distance and blended discussion forums. Although there was no way to confirm the investigator's interpretation of these events as none of the interviewees found their team in this situation, it appeared that the team and the moderator were under a great deal of pressure when this occurred as the tone of the posts suggested that information was being demanded as compared to being requested, and there seemed to be a lot of anxiety around exactly what time individual contributions would be available or edited.

These observations are in agreement with work by other authors (e.g. Xin and Feenberg, 2007), who suggest that the moderator needs to negotiate and set

expectations for how the team will work together. For example, in a post in a discussion forum from Don's team, the moderator asked "What do you suggest we do to ensure that everyone signs off on the document?" This query resulted in several responses, and the team established an editing order as a consequence. As part of that thread on editing the final document, the student moderator requested "Can I ask that when making corrections or changes, can we use track changes or highlight or something obvious, I don't know about everyone else but it makes it easier for me." Although the question was not directly answered on the forum, this request seems to have been followed as the various drafts of the document that appeared during the editing process did make use of both track changes and highlighting to demonstrate the changes that each student made to the document. These are examples of things that needed to be negotiated by both distance and blended teams, and were not necessarily visible in the online environment for either distance or blended teams.

Dean's team had a practice in which after a pair of students had a turn moderating, the students posted and gave the team some feedback about what their experience was. He thought that this probably arose spontaneously the first time it happened but that the team found it useful and continued the practice. Although this was the only example of moderators providing feedback to the team on the discussion forum, Dean felt that moderators in other teams likely also did this but that the feedback was provided offline. He suggested that was probably "the kind of thing that would happen in a coffee meeting" if they were working face-to-face rather than at a distance. As this behaviour was not observed for any of the other teams in the study, the suggestion of such feedback occurring offline is likely the case for the blended teams as well. He commented

It's the sort of thing you know especially if things aren't going well or something is kind of getting a little bit tense or something like that. Somebody's going to come along and say, 'let's do better'. It's the kind of thing where maybe two people who tend to chat a lot would sort of go by each other and chat all about it and say 'let's go tell so and so and make sure we do this this way next time'. I can see that kind of thing in sort of side conversations and pull together another person that's perhaps a leader how you'd see it, and between the three of you you'd go

and say, 'make sure you tell everybody and away we go'. And that would then be the plan right, this is how we're doing it" (Dean, 2010 distance student).

It seems probable that teams would undertake some kind of process to ensure that the same mistakes aren't made going forward through the four PBL cases, but that the process is likely occurring informally offline in the way that Dean has suggested it might. Dean mentioned that for his team, the general feedback went up on the discussion forum so everyone could see it, and the little side conversations about how to improve were happening offline either by email, Facebook or phone.

When asked if they found discussions with others to be important in developing their understanding of the course material in general and the PBL cases in particular, all four interviewees felt discussions were critical. Bob (2010 blended student) stated "We met a lot. But it fed into getting the clarification in getting to move forward. Had we not met so much, I think that we would not have been able to finally put anything together." Bev (2010 blended student) agreed "definitely for all of that course and program, talking to others and learning from them is pretty huge, it's a huge part of learning". They also all mentioned having specific people within the group that they felt were their best teammates for these discussions. Not surprisingly, these individuals and the interviewees appeared in the same self-selected sub-groups within the teams that worked more closely together as observed in the online PBL case discussions. Don (2010 distance student) noted

Everyone had their own groups. It seemed like there were lots of people on Skype, who were my go to people. It was definitely like after hours or whatever time of the night and that would be when I would bounce things off of people. These conversations to discuss problems were occurring offline – the medium was determined by the choice of the group as well as the technology that they held in common. One of the advantages to PBL is that it encourages discussion and students building on one another's ideas, something that the instructor thought was an important reason to incorporate it into the course design.

*Learning scaffold (LS) indicators.*

This section describes the use of the LS part of the CLS indicators in the course, why the investigator included them, how they were used by students and compares their use by distance and blended students.

At the time that the course was designed, the instructor was unfamiliar with the literature that would have helped with course design. As a result, the instructor made design decisions based on empirical observations of the classes that had been taught, several in-house workshops, and advice from the RRU instructional designers. The instructor felt that students supported their learning using a variety of scaffolds; some that were provided by the instructor, and some that they found on their own. As a result, a variety of supports or scaffolds were embedded in the PBL cases and in the course to support student learning. Jonassen (2000) points out that “if problem solvers do not believe in their ability to solve problems, they will most likely not exert sufficient cognitive effort and therefore will not succeed [in solving the problem]” (p. 71). The use of instructional scaffolds helps to support student success by providing assistance in limiting the scope of the problem and increasing learner confidence as they learn how to approach problems (Jonassen, 2011).

In order to best support student learning, it was important to determine what types of scaffolds were used most by students. There were a couple of drivers behind this question. The first was to determine if PBL was behaving as claimed. One of the major claims for PBL is that it encourages students’ self-study and independent research – that is, for students to read widely (Berkson, 1993; Gijbels et al., 2005). While the second was to determine if distance and blended students needed to be supported differently in their learning. The learning scaffolds (LS) can take the form of reading resources as well as materials designed by students (such as templates for tables) or posts by the instructor to provide as needed instruction. Table 25 has the full list of LS indicators with the behavioural examples.

The posts were assessed for indications of the use of LS. Similar to the approach used for the collaborative indicators, the discussion posts were read through looking for the ways in which the students were supporting their learning. The LS indicators developed into two groups – LS related to instructor and group organization, and LS related to citations or source materials.

The LS related to instructor and group organization indicators included instructor posts; action plans; templates; reposting of instructor information; and sign-up sheets (see Table 25, Results). Instructor posts were made to answer questions posed to the instructor; correct conceptual misconceptions; address class-wide problems and occasionally re-direct the discussion. These posts often represent “just-in-time” teaching moments that require the content expertise of the instructor to provide the student with intellectual support as they learn to identify and address knowledge gaps. The instructor’s method of choice for this just-in-time teaching is to ask questions to guide the student(s) in the appropriate direction to discover the answers and move their understanding in the appropriate direction. As noted by Xin and Feenberg (2007, p. 425), this is a well-established method to help scaffold or support student learning. Table 26 and Figure 13 demonstrate the significantly higher number of instructor posts in the distance team discussions as compared to the blended team discussions ( $p < 0.05$ ). Part of the difference is likely because blended students have the opportunity to ask questions in class and consult with the instructor in person; it is not surprising that they posted fewer questions to the instructor online. Additionally, many blended students came to the instructor during office hours to discuss their ideas or confusion about aspects of the PBL case problems prior to posting, resulting in a decreased need for the instructor to intervene online to correct misinformation. While some distance students did contact the instructor privately via emails or telephone, most students posted their questions on the team discussion forums.

The most noticeable examples of LS created by students were action plans and sign-up sheets (see Table 26). This is likely to be a function of the online discussion group being the primary means of communication for the distance teams as these are LS that tend to appear in the early meeting thread of the discussions. Distance student moderators usually post action plans as well as sign-up sheets in this thread as they outline the approach they want to take to the discussion and how they see the work being divided up. For blended teams, these steps usually take place in a face-to-face meeting that occurs before the online discussion begins. As will be discussed further below, this initial meeting is used to decide on the scope and approach to the problem as well as to divide up the work. As a result, the differences observed between distance

and blended teams in these two categories seem to be a result of the means of communication available rather than a difference in approach.

Although the distance teams had slightly more posts per team in the use of templates and reposting instructor information categories, the differences were not significant. The use of templates category was a function of how the team chose to organize their document assembly rather than how they communicated. Templates were created and used by both distance and blended teams, and were advantageous as they helped teams organize information collected by several individuals into a consistent format. The category of reposting instructor information occurred much less frequently than asking the instructor questions directly (see Table 26 and Figure 13), perhaps because students prefer to hear the information first hand, directly from the instructor.

In the design of the problems, several different types of supporting scaffolds that students could use were included – hard scaffolds (guiding prompts), references to textbook chapters, lecture speaking notes, and websites. For example, each problem contained some hard scaffolds for the kinds of information that was necessary to address the problem. In addition, information relevant to understanding each problem was also discussed in several chapters of the assigned textbook. Lecture notes summarizing the material in the text as well as supplementary material were provided on the course website. Although the PBL case problems may not have directly required the use of these sources of information, they could be a starting point for information to help students to understand the theory needed to address the problems and to help students to limit the scope of the problem. In some cases, website links to online databases that could be used as sources of information were also provided.

The LS related to citations or source materials were easily identified in the student posts because the posts contained bibliographic information for the sources that were consulted. This behaviour may have been influenced by the requirement for the team to produce a final team report for each of the PBL cases. As a result, student posts often contained properly formatted and referenced writing that was ready to be incorporated into the final case report document. Sources included references to lecture

notes; references to textbooks; references to websites recommended by the course or case; references to websites found by students and references to work experience.

References to textbooks and references to lecture notes were frequently observed indicators. Most references to textbooks were to the course textbook, however, this was not always the case. There were numerous examples in both distance and blended team discussions in which citations of textbooks for other courses in the students' respective BSc programs also appeared, including textbooks for Environmental Chemistry, Law, Hydrology, Industrial Processes, and Environmental and Applied Microbiology and Biochemistry. A similar problem exists with the lecture notes indicator as it appeared that students were using both the Ecotoxicology lecture notes as well as lecture notes for other courses in their programs as LS. The investigator thought this was a nice demonstration that the students were integrating information across courses in the program rather than the courses remaining as separate entities.

In the future, it would be interesting to break down the "websites found by students" indicator in more detail. For example, using separate indicators for primary literature, technical literature (e.g. CCME, IRIS, WHMIS), legislative guidelines, etc. The current indicator on its own shows that students are reading material that wasn't on the required reading list, but it would be interesting to show the breakdown. A future question in this regard may be if there is a difference between the distance and blended students with regard to the type of literature they are consulting. For instance, are the distance students with more work experience consulting more technical/ practitioner's literature than the blended students who tend to have little work experience in the field?

Distance teams posted more messages that cite sources in all categories except for references to websites found by students and references to lecture notes (see Table 27 and Figure 14). A series of independent *t*-tests demonstrated that the differences between the distance and blended teams were only significant ( $p < 0.05$ ) for the references to lecture notes and references to work experience categories (see Table 27 and B12). References to websites that the students located themselves occurred nearly three times as often as any other category, supporting the assertion that students were reading widely beyond the assigned readings for the course (see Figure 14). The

observation that blended students posted more messages per team that contained references to websites that they found themselves compared to distance students was based on the frequency counts of the indicators provided by NVivo. As this result was contrary to the impression of the data gleaned by the investigator during the initial read-through of the discussion forums, there was a need to look more closely at the data to account for the discrepancy.

### ***NVivo and manual coding of attachment citations.***

The way that coded data was tagged in NVivo appeared to be a possible cause of the discrepancy between the investigator's impression that distance teams found more website references on their own than the blended teams, and the NVivo-based frequency counts that suggested the opposite was true. When students added attachments to their posts, the attachment's name was present as a line in the header of the post. When the investigator coded the post, the attachment was opened and checked for any citations, and categorized as needed. The name of the attachment was then highlighted and coded to the appropriate categories in NVivo. The discrepancy in the data arose because the name of the attachment (see Figure 15) could only be coded to any particular code once for each code even though the unit of coding for the LS coding scheme as sentences, words and sentence fragments. In other words, regardless of whether the attachment contained one instance of a citation to a website the student found or many instances, the attachment could only be coded once to the 'website found by the student' indicator.

To test what influence this may have had on the data presented in Figure 14 and Table 27, a partial follow up review of the data was conducted. The 2004 distance and blended cohorts had their attachments opened and the citations were counted by hand for each instance of the LS categories. That is, if there were four websites found by students in an attachment, then it was scored as a count of four rather than a count of one (NVivo's count). When the results of the recounts for these two cohorts were analyzed, the overall conclusions of the analysis didn't change as the differences between the distance and blended teams were still only significant for the citations of lecture notes and work experience ( $p < 0.05$ ), although the difference for citations of

textbooks was nearly significant ( $p = 0.051$ ) (see Table 28 and B13). The 2004 distance teams did post more citations to websites that they found themselves than the 2004 blended teams (see Figure 16 and Table 28), confirming the investigator's initial impression of the data. It was not practical to re-code all the posts with attachments, but it is possible that the differences between the distance and blended groups would become more apparent if all the attachments were re-coded.

Fortunately, the LS citation indicators were the only set of indicators that were impacted by the use of attachments to the posted messages. Other authors have not mentioned the use of attachments to posts but that may be related to either the platform being used for the asynchronous discussions or any attachments may not have been a focal point of the study. The discrepancy between the manual and NVivo's frequency counts is only relevant due to the investigator's interest in the frequency of LS use. In other studies, any attachments would have been opened only to help determine what cognitive Cofl category the overall post fit into, and since those categories are mutually exclusive, it would not have been relevant that NVivo could only code the attachment name once to each category.

#### *Social indicators – Cofl model.*

While salutations didn't seem to be common in the discussion forums overall compared to the total number of posts, salutations were observed when directing a comment to a specific individual or to a particular subgroup within the team or assigning tasks to individuals. This section will discuss social presence indicators and how they were used by distance and blended teams in this study.

The initial read through of the discussion forums had implied that social presence indicators were more likely to arise in the distance team discussions rather than the blended team discussions, and that salutations were not commonly used. A series of bivariate Pearson correlations were run to determine if the Cofl social presence indicators varied with one another when the distance and blended cohorts were combined. It was expected that correlations might exist between the various social indicators because the relationships between indicators were established by previous studies (Garrison & Anderson, 2003). The cohesion indicator significantly correlated

with both the open communication and affective indicators ( $p < 0.05$ ), but they did not correlate with each other. As the open communication indicator was least frequently observed, it may not have occurred often enough to show a stronger relationship.

A series of independent *t*-tests was used to compare the use of each of the social indicators by distance and blended teams (see Table 29 and B14). The use of all three indicators (cohesion, open communication and affective expression) was greater for distance teams than blended teams, but the difference was only significant for the cohesion and affective indicators. This again likely reflects the use of the discussion forums as the primary means of communication for the distance teams because there is more sharing of anecdotes and teasing. These are social instances that occur more in established groups, and also reflect the need to have established social presence in a situation where you can't necessarily interact face-to-face with another colleague.

The lack of significance for the open communication indicator may be due to the most usual example of the behavior observed being asking questions of others or complimenting/agreeing with other's ideas, which were observed in both distance and blended teams. Cohesion was most commonly observed as salutations. The interesting aspect to the use of salutations was their placement. When the post was for the group in general, there was usually no salutation. However, salutations were used when directing a comment to a specific individual or to a subgroup. As a result, moderators are often the users of salutations as they are trying to draw the attention of particular individuals, usually in an effort to request more information or input from them. Within the smaller self-selected subgroups, the use of salutations seems to be reinforcing the small group as the posts often contain salutations. Interestingly, the instructor modelled the use of salutations by starting posts with "Hi folks..." or a greeting directed to the individual who addressed their comment to the instructor. The instructor's modelling of this behavior was intended to set the tone of interaction but given that the course occurs near the end of the programs when students are already familiar with each other and have formed groups of friends, it seemed likely that the established social groups in the class didn't require this reinforcement from the instructor. Although these social interactions are more obvious in the distance forums, it doesn't mean that this isn't occurring in the blended teams. One would expect the kind of responses that contribute

to group functioning and group cohesion in the blended groups to be taking place in a face-to-face format rather than online.

Social interactions provide the context for learning and a certain level of social comfort is needed for students to successfully discuss course content. As noted in the Educational Context section of chapter one, this is a benefit enjoyed by both distance and blended students at RRU. The strong social dynamic that develops in both distance and blended cohorts is thought to be the basis for the very high course and program completion rates reported by program faculty (Guilar& Loring, 2008)

*Exploration and integration posts containing citations learning scaffolds.*

Word documents or Excel spreadsheets were commonly observed as attachments to posts for both distance and blended students. Attachments to posts became more common as students began assembling either sections of the final case problem reports, or the entire report. Using attachments allowed students to format their posts using the common features in Word or Excel, whereas Moodle has limited capabilities available to format text and tables. It also allowed students to use the track changes features in Word for editing purposes, as it highlighted the changes that the author of the post had made to the document. As a result, it may have been easier for student moderators to assemble documents by cutting and pasting from the attachments than it would have been to cut and paste from the Moodle posts into a Word or Excel file which would then have to be extensively reformatted.

For blended teams, nearly half of the exploration posts and three quarters of the integration posts contained citations (see Table 30). In contrast, approximately one quarter of the exploration posts and nearly forty percent of the integration posts of distance teams included citations (see Table 30). For distance teams, integration posts connected not only theory from the literature but also ideas, viewpoints and experiences contributed by their team mates which may or may not have included citations. This reflects the role of the discussion forum as the primary means of communication for the distance teams – as a result, the forum is more than just an information collection point. It also supports the cognitive and social aspects of the team's learning.

Bob (2010 blended student) points out “I do remember being assigned specific questions to look at so that my posts were being useful to the end result.” Both Bev and Bob agreed that students were posting sections written in full sentences with properly formatted references that they were intending the moderator to be able to put into the final document. There is much less discussion on the forum for blended teams, and interviews confirmed that the cognitive idea building and social interactions to support the team’s learning are occurring offline. This is definitely reflected in the significantly fewer posts for blended teams, and fewer interactions between team members on the blended forums as compared to the distance forums.

*Posts with social cohesion and collaboration indicators.*

Use of social presence indicators can provide indications of which individuals in a team are working as subgroups, and allow the investigator to evaluate more than just the manifest content in the discussion groups. As noted above, salutations or other indicators of cohesion were relatively rare compared to the total number of messages. Students only seemed to use salutations that included an individual’s name either when they asked questions of them or when they assigned individuals a specific task or asked them to provide updates. For example, “Tony, can you explain more about...” or “Jane, when will you be posting your section?”. It was also noticed that students who were moderating tended to ask questions of the group. Independent samples *t*-tests showed that distance teams posted significantly more messages ( $p < 0.05$ ) for each of the three indicators, social cohesion (CofI), asking questions (collaboration), and moderating (collaboration). The three indicators also show strong significant correlations between each other ( $p < 0.05$ ). These results showed that they varied together (see Table 31), and supported the impression from reading the forums. Moderation for each case was done by a pair of student moderators. Student moderators asked more questions of the team and used more cohesive language than students who were not moderating for that case. The association of social cohesion, asking questions, and moderating behaviour suggests that when students are moderating, their interaction with the group changes in a similar way.

## **Interviews**

Interview results helped to explain the results of the thread maps and content analysis, and are therefore integrated into the discussion of those analyses where appropriate. In spite of the very small sample of four interviewees, the interviews provided some useful insights into the team process for online PBL case problems. The Results section contains a summary of some of the interview data, which will be further reflected upon in chapter six.

## **Concluding remarks**

The research questions revolved around how teams engaged in online PBL construct their knowledge and do critical thinking; and how scaffolding, prior experiences and the ability to meet face-to-face might impact the evidence of these behaviours as observed in the online transcripts. Garrison et al.'s Cofl model (2001) was expanded upon with the addition of a new indicator (organization) to the cognitive presence part of the model. The expanded Cofl cognitive indicators were useful for comparing the approach to online asynchronous PBL taken by distance and blended students at RRU. The development of the CLS coding schemes helped to highlight similarities and differences between the students selecting the different instructional options that may require different teaching and scaffolding strategies. The instructional objectives of the PBL case problems were to have students read widely, and use that knowledge to solve real-world applied problems. The investigator felt that the final reports for each case problem indicated that this was being accomplished. The research questions will be more explicitly reflected upon in chapter six.

## Chapter 6 Implications, Research Questions, Limitations and Future Directions

This mixed methods study examined the similarities and differences in the critical thinking exhibited by distance and blended undergraduate environmental science students during an online PBL activity. This study also examined some of the variables that impact the demonstration of critical thinking when engaged in online PBL.

Chapter six revisits the significance of this research project to the PBL literature, and how the study addresses the research questions. The limitations and assumptions of the study are addressed, followed by a discussion of how this research informs the investigator's teaching practice and interacts with the RRU LTM. The final section will discuss future directions for research.

### Why is this research significant?

As described in chapter one, this research project contributes to filling several gaps in the PBL literature. The literature gaps highlight the need for more PBL studies that:

- *examine PBL outside of the medical domain;*
- *go beyond comparing "traditional" lecture to PBL;*
- *fully describe the problem typology and the type of PBL used;*
- *compare a single type of DE with a face-to-face condition, and fully describe both conditions;*
- *examine online PBL; and*
- *examine the PBL scaffolding and its influence on critical thinking.*

How this study is useful in contributing to filling these literature gaps is reviewed in the following sections.

#### **PBL studies that examine PBL outside of the medical domain.**

PBL was first developed for use in medical education, and although its use has since spread into other disciplines, the majority of research papers are from medicine or the health sciences. Walker and Leary's 2009 meta-analysis of 201 quantitative studies that compared PBL vs a lecture control suggested that "PBL may do best outside of medical education and allied health, when assessment is at the application rather than the conceptual level". Additionally, many review papers (e.g.:Dochy et al., 2003; Gijbels

et al., 2005; Jin & Bridges, 2016; Walker & Leary, 2009) have noted the lack of PBL studies from disciplines other than medicine for comparison purposes. This study is focused on the online participation of undergraduate science students who are enrolled in an Ecotoxicology course within an interdisciplinary Environmental Science BSc or Environmental Management BSc program. The PBL component of the course, the laboratory exercises and the scenario portion of the final exam are all application-based assessments.

### **PBL studies that go beyond comparing “traditional” lecture to PBL.**

The purpose of this mixed methods study was to compare distance and blended undergraduate environmental science students with respect to the demonstration of critical thinking indicators and the factors that impact their demonstration when engaged in online PBL using asynchronous discussion forums. It should be noted that this is not a comparison of traditional lecture versus PBL instruction. Rather, it is intended to demonstrate the relative impact of PBL on various aspects of student learning and satisfaction as both distance and blended students were engaged in online PBL discussion forums. From this it is hoped that we might gather evidence regarding how to best support both types of students in their use of online PBL.

### **PBL studies that fully describe the problem typology and the type of PBL used.**

The type of problem and type of PBL used in this study are described using Jonassen’s (2000) problem typology and Barrow’s (1986) taxonomy of PBL variants in the following sections. Jonassen (2000) described eleven types of problems that were distinguished based on characteristics such as how ill-structured and complex they are. This problem typology is useful when trying to design scaffolds to help support students learning to solve different kinds of problems (Jonassen, 2011; Jonassen & Hung, 2008). Barrows (1986) described six variants of PBL that can be distinguished by the amount of free-inquiry expected from students and the role of the instructor (see Table 1).

### ***Problem type.***

PBL is based on the use of ill-structured problems. Ill-structured problems are useful in modelling professional practice because they contain many of the same characteristics found in authentic professional problems. Specifically: the problem is initially presented in an incomplete form (Barrows, 1996; Koschmann et al., 1994); the problem evolves over time as more information is obtained; decisions must be made based on incomplete information or an incompletely defined problem; and that uncertainty may persist about whether or not the correct decision or interpretation has been used (Koschmann et al., 1994). These problems can easily be multidisciplinary, which in the context of the Ecotoxicology course examined in this research is particularly advantageous because the course is one of the two capstone courses in two multidisciplinary BSc programs.

Jonassen (2000) classified problems into categories based on their characteristics. This is useful as different types of problems may require different kinds of scaffolds to support learning, and different skill sets to solve (Jonassen, 2011). The four PBL cases used by the teams in this study were all classified as decision-making problems; however, the last two problems also contained design elements. In case three, the students are expected to design a sampling plan for contaminants and a work plan for summer employees for the town. In the final case, students are expected to design and recommend remediation plans for the community. The PBL cases that were designed for this course were based on elements of many actual case studies and were combined into a fictional context. The four problems were interrelated as the same fictional community was used as the location. Decisions that students make during earlier cases impact the options that they have available in the later cases. For example, in case one, the team decides on what chemicals are present and of concern in the local industries' waste streams. This decision ultimately limits which chemicals can potentially be chosen as the available focus for designing the remediation plan in the fourth problem.

It is not just the type of the problem that will impact student success in solving it, aspects of the students themselves and their behaviours also have influence (Jonassen, 2000). Jonassen (2000) notes that "engaging intentionally, exerting effort, persisting on

task, and making choices, also affect the effort that students will make in trying to solve a problem” (p. 71). For the distance teams, the discussion forums are a primary means of communication so these behaviours may be more observable in the form of more frequent posts and more evidence of collaboration in their posts. The social interaction between members of the team may support student motivation to contribute to the group’s work, and reinforce the idea that together the group can solve the problem.

This is particularly true of larger scale problems like the fourPBL case sequences that were the focus of this research because these decision-making problems were heavily scaffolded to support student success in the earlier cases in the series. The scaffolds in case one and two increased learner confidence and interest, and allowed students to develop their problem solving skills. Each of the first three PBL cases contained some “solutions” of an intermediate nature, but the final “solution” to the scenario wasn’t available until the conclusion of the final PBL case.

### ***Type of PBL.***

Very few studies explicitly name or describe the type of PBL that was used in the study. This problem becomes particularly apparent when looking at review papers such as Walker and Leary (2009). They noted that only five of the 201 studies included in their analysis mentioned the type of PBL in use (Walker & Leary, 2009). This makes comparisons between studies problematic as there are a number of different possible forms of PBL, ranging from lecture-based cases in which content is covered in class, followed by the use of summary problems to highlight key points; to problem-based and closed-loop PBL, which emphasize free inquiry with support of teachers (Barrows, 1986). The difference between problem-based and closed-loop PBL is that closed-loop PBL includes a solution-critique stage (Barrows, 1986).

The online PBL in the Ecotoxicology course that is the focus of this study is of the Problem-based type. Problem-based PBL is characterized by free inquiry in small groups guided by teachers who support the team’s learning (Barrows, 1986). This style of PBL helps to emphasize both the critical thinking and collaborative skills that are valued in the RRU LTM (Royal Roads University, 2013b). This method is differentiated from the closed-loop model which requires students to explicitly critique their method and solution to the problem (Barrows, 1986). Interestingly, there was some evidence

both in the team discussion forums themselves as well as the interviews that such critique was taking place informally within the teams.

In this study, the problems were designed by the instructor based on details taken from a variety of real-life situations but combined in a fictional context. The intent was to expose students to authentic problems, that do not allow students to simply “look up the answer” on the internet. The use of authentic problems is part of the RRU learning and teaching culture and has also been integrated into the LTM (Royal Roads University, 2013b). An important instructional goal for this course was that students read and critically consider their source material rather than simply looking up an established solution. This requirement for students to engage in free-inquiry distinguishes the problem-based type of PBL from other types of PBL, such as case-based lectures or case method PBL in which independent research is not a required part of the instructional design (Barrows, 1986).

**PBL studies that compare a single type of DE with a face-to-face condition, and fully describe both conditions.**

This undergraduate Ecotoxicology course is taught as part of two multidisciplinary BSc Programs. The Environmental Science program is a blended program, and the Environmental Management program is a distance program. As a result, the Ecotoxicology course is offered in both a distance and a blended form, depending on which program it is being offered in. The distance version of the course is delivered online with the laboratory section of the course offered during the final of the 3 three-week residency periods. The blended version of the course combines a face-to-face delivery of both lectures and laboratory experiments with an online PBL component. Both versions of the course include laboratory experiments, presentations, discussions, and an ongoing customized series of PBL cases. The PBL component is made up of a sequence of four linked cases, which unfold as the course progresses. The PBL cases offer a concurrent opportunity for applied learning to support the theory that is being taught in the classroom for the blended group and through the readings for the distance group. The PBL cases account for one-third of the course work and mark, and are conducted through online asynchronous discussion groups regardless of the

instructional model used for the rest of the course. The final exam (including the PBL-like scenario) is a face-to-face exam for both the distance and blended classes and accounts for 25% of the course grade. The use of the online PBL component was meant to help students to fully integrate the theory and practice of Ecotoxicology in a meaningful way. Both are 14-week, 4.5 credit courses. In addition to the required readings, the blended group receives 3 hours of face-to-face lecture per week, while the distance group has access to the lecture notes but no lectures. The most recent versions of the course that were not included in this study now also include the use of short videos.

In this study a single type of distance education platform was used for the PBL component of the course—asynchronous discussions. This design choice was made primarily to allow students to have time to consider and research prior to posting. It also allowed teams to include members that live in different time zones (distance students) or that have different study or work schedules. The use of asynchronous discussions by both distance and blended students allowed the comparison of how students approach the problems, what supports they use and what activities are occurring offline.

### **PBL studies that examine online PBL.**

Although most applications of PBL are in a face-to-face format (McLinden et al., 2006); this study was focused on an online PBL activity that occurs in both the distance, and blended versions of an undergraduate Ecotoxicology course. As distance and blended education offerings become more common in the post-secondary sector, the question of how PBL can be adapted to the distance environment is being more closely considered (Barrows, 2002). This study is particularly of interest to institutions such as RRU with its strong emphasis on distance and blended educational programs, and with regard to how best to support the integration of teaching methods like online PBL for different types of students who may bring different experiences to their cohort.

### **PBL studies that examine the PBL scaffolding and its influence on critical thinking.**

This study looked at the effect of learning scaffolds (LS) on the critical thinking of undergraduate science students as expressed in online PBL case discussion forums.

This contributes to the literature in two ways: the addition of a new indicator (organization) to the cognitive presence part of the Cofl model, and the development of indicators for a LS coding scheme.

The Cofl cognitive indicators were used to determine which posts contained evidence of critical thinking. The assumption that the discussion posts could be adequately assigned to one of the Cofl cognitive indicators did appear to be upheld for posts that fit the criteria for the triggering, exploration, integration and resolution indicators. By adding the organization indicator to the Cofl cognitive indicators relatively few posts were categorized as “other”. After this adjustment, most of the “other” posts were either purely social or posts by the instructor. The addition of the organization indicator contributed to the identification of the major discussion approaches as well as online meetings in the thread maps. It also helps to capture the peer-to-peer teaching presence that is necessary for the organization of the discussion, and supports the group’s critical thinking.

A series of indicators and behavioural examples were developed to characterize the various LS used by students to support their learning. Although the hard scaffolds present in the problems were faded in subsequent cases, students continued to read and select LS such as reference materials beyond the textbook and lecture notes, and became able to appropriately identify and fill knowledge gaps. Students also integrated information from a variety of disciplines into their work. Guidance from the instructor also played an important role in supporting students’ critical thinking for both distance and blended students.

### **Reflecting on Research Questions**

The previous section focussed on how this study contributes to the general PBL literature. This next section describes how the results of this study help to address the research questions that guided the study. Each question is used as a subheading for this section.

**How does the online asynchronous PBL forum activity of distance and blended students differ? How does this approach change over time?**

This section looks at the differences and similarities in the activity of distance and blended students with respect to their choice of the primary communication medium; use of organizational messages; use of an initial organizational meeting; and the use of self-selected subgroups to support their learning. Discussion style, document assembly choices, feedback and conflict will also be discussed.

The first difference in approach relates to the commitment to the use of the discussion forum as a place for exchanging and discussing ideas. One of the early assumptions related to the content analysis approach was that both distance and blended students would be equally motivated to use the online discussion forums. This initial assumption appears to be false. The distance teams who do not have the option to meet in person for discussions, post more messages per case, have longer threads with more contributors, and more instances of indicators of collaboration than the blended teams do. These differences reflect that the discussion forums are the primary mode of communication for the distance teams but not for the blended teams. As Bev (2010 blended student) pointed out “I don't ever remember the online forums being the main form of communication.” Although the interviews indicated that the distance teams could, and did, use other communication tools such as MSN or Skype, particularly among the small subgroups that developed within teams, the majority of their work happened on the discussion forum. In contrast, blended teams were both able and more likely to meet face-to-face (offline), and this impacted their use of the online discussion forums.

This fundamental difference in the choice of the medium for the primary means of team communication changes the nature of the use of the PBL discussion forums. The distance teams used the discussion forums for their teamwork with meetings, exchange of research, discussion and document assembly occurring on the discussion forum over the course of several days to weeks. In contrast, blended students conducted team meetings and often document assembly face-to-face, and used the online forums primarily as a mechanism to report out on the research of subgroups and individuals. This point is supported by the higher proportion of exploration and integration posts that are properly formatted with citations ready for inclusion in the final report documents for

the blended teams than the distance teams. In addition the blended team forums contained fewer instances of collaboration indicators and discussion in compared to the distance team forums.

Another difference in terms of approach was in the use of organizational messages. The distance teams posted significantly more organizational messages than the blended teams. This is in agreement both with the greater proportion of distance teams than blended teams that used an organizational scaffolds approach (65% and 46% respectively), and with the observation that the distance teams often began their discussions with an rapid exchange of organizational posts that represented an asynchronous online meeting. Interviews confirmed that both distance and blended teams had an initial meeting for the purposes of getting organized, determining project scope, delegating responsibilities, negotiating internal deadlines, and resolving any initial confusion. This is in agreement with Xin and Feenberg's observation that "intellectual engagement in this early phase does not generally aim at achieving agreement, but rather at defining terms and problem boundaries, clarifying statements and context, and proposing approaches" (2007, p. 423). The initial meeting occurred on the forum for distance teams and usually extended over a couple of days, depending on team member availability. For blended teams the initial meeting occurred face-to-face. The ability to meet in person potentially gave the blended teams a time advantage because they had the possibility of getting started on their research sooner, but this did not seem to translate into better overall results on the PBL case reports.

Both distance and blended teams broke the PBL case into tasks that were taken on by individuals or small self-selected subgroups. In the distance teams, the subgroups tended to be based on who had media in common (e.g. Facebook and Skype) or who they had worked with closely in previous courses. In blended teams, the subgroups tended to be based on the small (three person) groups used for laboratory work in the course. The membership of the subgroups appeared to be consistent throughout the course. The interviews also indicated that the subgroups tended to include the people that the interviewee identified as individuals that they tended to go to for assistance when needed or just to talk, brainstorm or clarify ideas and research directions. This suggested that these offline discussions were important in supporting the higher order

thinking of the teams. This suggestion was confirmed by all four interviewees who stated that offline discussions were important to their understanding of the PBL cases and the course material overall. These discussions—whether asynchronous and online, or largely synchronous and offline are an example of the kind of collaborative behaviour that PBL should be encouraging, and also makes PBL a good fit for the RRU LTM and the learning outcomes for the BSc programs (see Appendix C).

Interviewees indicated that they thought their teams used a consistent approach to the four PBL cases. This interpretation of a consistent approach is in agreement with the investigator's observations of the discussions forums. Most teams (30/34) chose to apply either the organizational scaffolds or the organic approach to at least three of the four PBL discussions. Of those 30 teams, 15 selected a single discussion approach while 15 changed approach only once). Interviews indicated that the moderator typically decided on the discussion approach, and that the approach chosen wasn't discussed during the initial team meetings. Interestingly, it was unusual for teams to change their approach more than once with only 4/34 teams doing so. Similarly, both distance and blended teams tended to choose one method of document assembly (24/34 teams) and stick with it (e.g. template-based assembly, sectional assembly or end point assembly). Distance teams tended to assemble their final report documents on the forum, whereas blended teams tended to assemble them offline.

Although only one distance team showed explicit evidence that feedback within the team was being used to modify the team's approach and performance, interviews indicated that this was likely occurring in the background for both distance and blended teams. Similarly, conflict was more likely to be dealt with off of the forum, especially for blended teams where it was more likely to erupt during the face-to-face meetings, be quickly resolved during the meeting and not discussed online. While conflict was rarely observed in the distance team discussions, the relative "permanence" of any writing about the conflict seemed to prolong the conflict and hard feelings about it. The common sources of conflict that were mentioned in interviews included: individuals that pushed for control of editing or moderating when it wasn't their turn; not meeting team deadlines; and frustration with team members who would not, or could not, produce

work of a sufficient quality to be integrated into the team report without substantial rewriting.

The distance and blended students differed with respect to their choice of the primary communication medium; and use of organizational messages. They showed similarities in their use of an initial organizational meeting, and the use of self-selected subgroups to support their learning. Teams tended to choose a discussion style and document assembly method and consistently used it for at least three of the four cases. Although moderator feedback about their approach and conflict were only rarely observed on the distance discussion forums, interviews indicate that both occurred off the forum for distance and blended teams.

**In what ways do the levels of critical thinking observed in students from distance and blended courses differ in online PBL situations? What elements influence this?**

The critical thinking observed in student posts was expressed using the PBL-CT scores, which represented the total number of exploration, integration and resolution posts made by a student across all four PBL cases. Factors that influenced the number of each of these types of posts will therefore have influenced the PBL-CT scores for individuals and teams. This section will describe some of the influences on the PBL-CT scores including primary communications medium, and team approaches to the PBL cases (e.g. document assembly, moderation influences, and offline activities).

The distance teams posted significantly more exploration, integration and resolution posts than blended teams, resulting in greater PBL-CT scores. This is interesting because 44.1% of distance posts and 74.5% of blended posts contribute to their respective PBL-CT scores. The blended teams' tendency to use the discussion forum primarily as a place to post work that was ready for the moderators to add to the final case report may be a cause of the much higher proportion of the total blended posts that contribute to their PBL-CT score as compared to distance teams.

Exploration posts are often brainstorming or sharing ideas with minimal or no literature support required (although exploration posts often do contain paraphrasing from a single citation source). They usually appear earlier in a thread than integration posts. It appears that these types of activities occurred during face-to-face meetings for

the blended teams and as a result, at least some of the exploration activities of the blended teams ended up being undocumented. This supposition is supported by interview statements from the two 2010 blended students (Bob and Bev) who both expressed how valuable meeting and discussing the case problems with other students was to their learning. The significantly greater number of integration posts posted for distance teams than for the blended teams on each case may be reflecting both the greater use of the forum overall as a communication tool for distance team as well as the tendency for the distance teams to assemble their final report on the forum, which requires integration of ideas from multiple individuals and multiple sources. Similarly, the significantly higher number of resolution messages per case for the distance teams than the blended teams may reflect the tendency for distance teams to assemble and edit their final report on the forum, which requires the moderators to assemble and post the draft document for critique by the rest of the team. Additionally, many moderators for blended teams did not post either drafts or the final version of the document which was handed in, which reduced the number of resolution messages.

The use of Google Docs and templates were two other decisions by the teams that may have influenced the students' PBL-CT scores. The decision to use either of these methods appears to have been largely up to the moderator. The use of Google Docs reduced the number of critical thinking posts because more of the work that would generate exploration, integration and resolution posts was done off of the discussion forum directly in the collaborative document, resulting in a reduced PBL-CT score. While the use of Google Docs was not a large influence in this study because only two distance teams adopted this method (data in this study is from 2010 and earlier), it is becoming more popular and will need to be considered in terms of evaluating online PBL work in future studies.

The use of templates in document assembly resulted in more integration posts than would have been expected occurring earlier in the discussion. The use of the templates seemed to make it easier for the moderators to assemble the final document and established the level of detail that was required. As a result, the team's research tended to be quite directed; this sometimes resulted in rapid progress, and made it easier for the moderator to incorporate late additions from team members who were

lagging behind internal deadlines. When moderators chose to use templates, the number of integration posts increased, and therefore the team's PBL-CT score was higher than when end point assembly was used.

As expected, offline activity was a major influence on the PBL-CT scores. The blended teams had the ability to meet face-to-face, and that appeared to be their preferred mode of communication. Interviews confirmed that small group meetings were a critical part of students' developing understanding. Given that there was a considerable amount of collaboration and higher order thinking going on that was not captured in the discussion forums for the blended teams, their overall PBL-CT scores were lower than those observed for distance teams.

All interviewees expressed that they felt they had greater creative control of the final document and made more effort to be collaborative when it was their turn to moderate with their partner compared to when they were not moderating. They felt that their role was to guide the discussion and try to ensure that the discussion output was sufficient to address all the aspects of the case problem. Moderators often made less exploration and integration posts because they input their information directly into the document that they were assembling rather than posting to the discussion group first. This was offset by more organizational posts by moderators. If the moderators chose to assemble the case report on the discussion forum, then the moderators made more resolution posts than they would have if they had not been moderating.

Thus, PBL-CT scores are influenced by the primary communications medium, team approaches to the PBL cases, member role, and moderator decisions.

**How do the observed levels of critical thinking change as students from distance and blended cohorts progress through a sequence of four PBL cases in the Ecotoxicology course?**

The mean PBL-CT scores for the teams were relatively consistent as the teams moved from case one to case four. Although the posting behavior of the moderating student was altered compared to when they were not moderating, the posting changes were very similar within the same team, so the overall mean team PBL-CT score remained relatively consistent from case one to four.

Although the number of scaffolds embedded in the case decreased as the teams progressed from case one to case four, the PBL-CT scores remained relatively consistent. As the number of hard scaffolds in the PBL cases decreased, students seemed capable of self-identifying information gaps and how to address them. The hard scaffolds provided in the case were particularly important in the first two PBL cases as they helped students to limit the scope of the problem. Jonassen and Hung (2008) note that limiting problem scope helps students to better assess what knowledge and skills will be needed to solve the problem and decreases the complexity of the problem. Other authors have suggested that as students become more familiar with the PBL process that they may require less guidance (e.g. Barrows, 2002; Hmelo-Silver, 2004; Hmelo-Silver et al., 2007). It seems reasonable that it is not just a matter of becoming familiar with the PBL process—it also requires the student to become familiar with the course expectations through teaching presence expressed as instructor posts and as timely feedback on the team PBL case reports. The case one team reports were often not the strongest of the four PBL case reports as when case one was due; students were still in the process of establishing instructor expectations.

The PBL-CT score results were based on student contributions to the discussion forums only – they did not capture activity that occurred off the forum. The instructions for the assignment also influenced participation in the online discussion by the blended cohort. In 2009 the instructions for the online discussion were changed so that if the student did not participate in the forum, then they would receive a grade of zero for the team report. This change did not have a noticeable impact on the mean PBL-CT scores for the distance teams; however, the 2009 and 2010 blended cohorts had significantly higher mean PBL-CT scores for all case problems compared to the 2004 and 2006 blended cohorts. The requirement for students to demonstrate an online presence seems to have encouraged forum activity by some blended students who may have been less likely to post in previous cohorts. It seems likely that this change was not observed in the online activity of distance students because the discussion forum is their primary means of communication with their teams.

As the discussions continued, students became more comfortable with each other and sharing their experiences, as well as integrating the “elements of the

disciplinary tradition” into their discussions (Xin & Feenberg, 2007, p. 14). These social structures within the cohort support the learning and collaboration between the members. Xin and Feenberg (2007) note that social interactions can result in “shared understandings rather than unanimous agreement” (p. 424). Depending on the style of the problem posed, it may be more appropriate for a team to come to a shared understanding – many problems are less about determining a single solution and much more about the team understanding the complexity of the problem as well as the variety of potential solutions or approaches. For the problems used in this study, the creation of the final report required teams to account for the various viewpoints of the members as well as the interdisciplinary nature of the course material.

In sum, PBL-CT scores for the team remained relatively consistent as teams progressed from case one to case four and the number of hard scaffolds was faded. This implies that both distance and blended teams became more able to self-identify and fill knowledge gaps as they progressed through the sequence of case studies. PBL-CT scores do not capture offline activities, and as a result, tend to be lower for blended teams than distance teams.

**Is there evidence that student posts containing critical thinking indicators affect the participation of students in following posts?**

Critical thinking discussion posts sometimes acted as scaffolds for other members of the group, and lead to more critical thinking posts. This was frequently observed as it related to document assembly. For example when teams used template-based assembly, a series of integration posts resulted from the team’s ideas being quickly built on one another. Similarly when teams assemble their final documents online, a draft is posted (resolution post) followed by a series of integration posts representing substantial changes to the draft document. These integration posts eventually culminated in a final resolution post that includes the final version of the PBL case report. Teams that used sectional-assembly (that is, when small subgroups built up the ideas for a particular section) were observed as generating a series of exploration posts that culminated in an integration post that brought together the ideas and work of the subgroup.

The pattern of several critical thinking posts building towards a final post that integrates those ideas is easier to observe in teams that used the organizational scaffold approach to their team discussions. Because the threads were clearly organized under an initial post for each organizational scaffold, the series of exploration and integration posts that replied to the thread demonstrated that the critical thinking posts were leading to, and connected with more critical thinking posts. These patterns may also have been related to the requirement for the team to produce a report for each case that summarized the discussion and addressed the question, as it encouraged students to build towards writing posts that could contribute to that report.

For blended teams that use the organic approach to the discussions, this doesn't always appear to be the case. There were many examples of case discussions in which each thread consisted of only a single post, and the posts themselves were not obviously connected. These discussions felt the most discontinuous – and were the most obvious examples of discussions acting as a location for the moderators to pick up the research work being done by the team rather than acting as an exchange of ideas.

Critical thinking posts therefore can act to scaffold and encourage other posts that contain critical thinking indicators. This seems to occur most often when documents are assembled on the forum; when teams use sectional assembly methods; or when teams use the organizational scaffolds approach to the discussion.

**Is critical thinking more apparent in subjects where students have more prior work experience? How do students with more work experience use that experience within the group discussion? Do they use it to scaffold the critical thinking of their group?**

The investigator initially felt that work experience might be an important scaffold for distance students, most of who have been in the workforce for some time. It was also expected that they might support the team's learning by sharing their experiences in the online discussions.

There was only one example of a student in the blended teams referring to work experience. There may have been a variety of reasons for the lack of references to work experience by blended teams. Many blended students entered the BSc program directly from their college program and do not have any work experience. Others, like the blended interviewees, may not have had any science or research-based experience to

share. Alternatively, work experiences may be an example of information that was shared in person rather than being posted online for a blended group. In contrast, the distance teams show 121 instances where work experience was explicitly referenced. Both distance program interviewees had more than ten years of course-relevant work experience in environmental compliance and sampling; and environmental consulting respectively. The distance interviewees both had work experiences that were relevant to the case problems, and felt that they were able to support their team by highlighting the practical aspects of their experience and how the theory that they were learning fit into that experience. The posts in which a student referred to their work experiences directly (e.g. “At the mill I worked at we did testing this way...”), were often followed by questions or requests for more details by their team mates. As the intention of the PBL cases was for students to discuss practical problems, the inclusion of students with environmental work experience appeared to improve the learning experience and discussion of the applied problems.

One of the blended interviewees (Bob) who had a lot of non-environmental work experience, felt that his “people-skills” contributed to the smooth functioning of his team. Although his experiences didn’t directly scaffold the course-content related critical thinking of the group, he did note that his life experience was valuable in dealing with more confrontational group members, and assisted him in knowing when to compromise and when to argue further. This kind of skill set may help these individuals to better perform as moderators, who can encourage collaboration.

Both environmental and non-environmental work experience can make valuable contributions to the team. Environmental work experience may help to stimulate conversation and introduce practical aspects of how theory is actually applied, while non-environmental experiences may help to support the collaborative skills and manage personalities and conflicts within the team. In future, it may be useful to survey students prior to the start of the course to determine what environmental or other work experience they have in an effort to more evenly distribute such experience across the teams.

**What types of scaffolds are used most by students? Are there differences in use across students from distance and blended courses? Is there**

**evidence in the discussion posts that the scaffolds used by students support their critical thinking?**

This section defines LS, how citation LS were used by distance and blended students, and how group organization and instructional scaffolds were used by teams.

Learning scaffolds (LS) are items or behaviours used by students to support their learning. LS can range from questions posed to the instructor, to reference materials that may be consulted, to materials that students create such as templates or action item lists. In some cases scaffolds are designed by the instructor in advance and provided to the class (hard scaffolds) while in others they are dynamic and used or developed on an as needed basis. Dynamic scaffolds might be just-in-time direct instruction by the instructor or facilitating discourse (two indicators of teaching presence in the Cofl model (Garrison et al., 2001; Garrison & Arbaugh, 2007)). In this study, the LS fall into two major categories – citations sources LS, and instructor and group organization LS.

The citations scaffolds were often observed in posts that contributed to the critical thinking score. For the blended groups (especially the latter two), a greater percentage of both the exploration and integration posts contain citations than for the distance group. This appeared to be a reflection of both the requirement to post a minimum number of posts per week as well as the blended teams using the discussion forum as a collection point for information. The posts were formatted as full paragraphs and sentences with complete citations to make it easier for them to be integrated into the final document by the moderator. For the distance teams, at least some of the exploration and integration posts contained uncited material; either because they represented brainstorming activities or an exchange of ideas about how topics related to one another. These uncited posts eventually developed into posts that were ready to be integrated into the final document i.e., written in full paragraphs and contained properly formatted citations.

Students from distance and blended courses used different combinations of scaffolds to support their learning. Both distance and blended students used websites that they found themselves more than any other citation LS, with the distance teams posting slightly more times per case referring to textbooks and course/case recommended web databases than blended teams. The distance teams also drew on

their work experience more frequently per case (there are almost no references to work experiences by the blended teams). PBL is thought to encourage students to read widely (Berkson, 1993; Gijbels et al., 2005), which appears to be what has occurred. Both distance and blended teams were reading beyond their textbooks and lecture notes, and were locating and selecting reference materials to support their learning. A references section was included in the case reports, but was not analyzed as part of this study. In future, it would be of interest to further inventory the reference materials that students are finding on their own to determine how much of it is from the primary literature, technical literature, government reports, etc. It would also be of interest to know if the students with significant work experience are more aware of technical literature and government reports.

The distance teams used their textbook, course recommended databases and work experience more frequently per case than the blended teams. Although the lecture speaking notes were provided online to both distance and blended groups, the blended students used their lecture notes more frequently than the distance students. The blended students had the opportunity to add their own additional comments to these lecture notes during class - personalizing them and highlighting areas of specific interest to a particular student. This may have made them more attractive as potential source materials for blended students than they were for the distance students for whom lectures notes were simply another form of source material.

It was an instructional design goal for the course that students read widely within the literature for the field. Addressing the PBL cases thus required students to find and use a variety of different source materials including: lecture notes, websites, textbooks, etc. The content analysis suggested that students were reading widely. Interviewees were asked when and how they used the various possible learning scaffolds (source materials). Bob(2010 blended student) started his research with the materials that were provided (lecture notes, textbook and suggested websites) and then moved onto finding more sources once “we started putting [the solution to the case problem] together and analyzing it that we started thinking outside that box and started pulling additional resources that we felt needed to be filled in.” Bev(2010 blended student) found that she used the lecture notes extensively, and was then “doing a lot of research, looking for

some peer-reviewed literature.” She noted that she didn’t often use the course textbook. Dean(2010 distance student) used the lecture notes and the textbook as jumping off points for further research in the literature. Don (2010 distance student) noted that he started with the lecture notes because they “focused on some of the stuff we were going to need as well.” He then moved to the textbook and other research materials. The common theme was the use of lecture notes and the textbook as starting points before moving onto personal research as they delved further into the PBL cases.

When designing the categories "reference to textbook" and "reference to lecture notes", the investigator had the use of the textbook and lecture notes for the Ecotoxicology course in mind. It was interesting to find, however, that these categories also ended up including references to the textbooks and lecture notes for other courses that students were taking or had taken in their programs. Given the position of the Ecotoxicology course in both interdisciplinary programs, and that it was meant to allow students to integrate and transfer knowledge from other disciplines as well as Ecotoxicology, it was nice to see evidence that this was actually occurring through the student's selection of source material. In future, it would be of interest to further examine the breakdown of which courses are most often being referenced in order to strengthen these cross-curriculum connections, and enhance connections with courses that are not so obviously connected.

Another type of scaffold is represented by scaffolds that allow students to organize how they work together. This type includes posting action plans, templates, sign-up sheets, reposting instructor information, and posts from the instructor that address questions directed to the instructor (see Figure 13). In all of these cases, the distance team had significantly more examples of action plans, sign-up sheets and instructor posts than their blended counterparts. Some of these activities (making an action plan, creating templates for various parts of the work and sign-up sheets to volunteer to do specific parts of the work) are things that would often happen during an initial face-to-face meeting for the blended class, whereas they are explicitly posted for the distance class. In a similar way, students in the blended class were more likely to ask the instructor questions in a face-to-face setting rather than doing so online - both to

see the instructor's reaction to the question, and to be able to ask follow up questions where needed.

The "reposting instructor information" category includes posts in which the student usually leads with "I asked the instructor, and she said..." or "I emailed the instructor this question and she said..." This behaviour was engaged in by both distance and blended students, and was often instigated by the group discussing a problem and then one individual was delegated to seek clarification from the instructor rather than several people doing it on their own. This is both a scaffold for learning as well as evidence of collaborative behaviour both within the group and between the group and the instructor, and may lead to further discussion within the group. Posts that represent interactions with the instructor (either direct or indirect) are more likely to occur in the middle time points of the discussion, after the group has had some time to get started on their research and has realized that they may need clarification.

In addition to the dynamic scaffolds described above, the PBL cases were designed with some hard scaffolds. Both distance and blended teams made use of the hard scaffolds provided as demonstrated by the fact that the team reports were complete and therefore made use of the hard scaffolds to limit the scope of the problems. When the moderator chose to use the organizational scaffold approach, the hard scaffolds were used to organize the discussion into discreet threads. These posts did lead to critical thinking posts as exploration and integration posts were gathered under the posts to form threads.

The results of this study suggest that students used learning scaffolds extensively, and that they were important in supporting their learning. The choices in scaffolds used by distance and blended students are influenced by their primary mode of communication as well as their organizational approach to the discussion.

### **Limitations and Assumptions**

The limitations of this study include offline activity, non-randomized assignment of students to distance and blended cohorts and assumptions around the content analysis of the online PBL case discussion forums. This section will discuss these limitations and assumptions.

**Offline activity.**

Online asynchronous discussion forums can provide evidence to support the evaluation of higher order thinking (PBL-CT), collaboration and writing, especially for distance cohorts who use it as their primary form of communication. However, for blended cohorts most of the discussion, collaboration and social interactions appear to be occurring offline where it cannot be observed. As a result, PBL-CT scores for blended teams are lower than the scores of distance teams. Likewise both social and collaboration indicators were observed in the blended discussion forums but with much lower frequency than for distance forums.

**Non-random assignment.**

Similar to other studies noted in Albanese & Mitchell (1993), the data collected for this study were not based on randomly sampled or randomly assigned individuals. The students were divided into distance or blended cohorts based on their choice of registration into a particular program. It is unlikely that the data could have been generated from a random assignment of a population of distance or blended students in this context as adult students choose their programs based on their assessment of their needs (whether financial, social or intellectual) as well as their instructional preferences. Although pragmatic considerations appear to carry the most weight with students when choosing between distance and blended instructional models, over the years students have transferred from a distance to a blended program because they found that they needed to be in a situation where they knew they would be in a classroom with other students at a certain time each week. Likewise, students have transferred from a blended program into a distance program due to changing life circumstances.

**Content analysis assumptions.**

The primary source materials for this study were the compiled PBL case discussion forums. There are number of assumptions inherent in any analysis of asynchronous threaded discussion transcripts including:

- a. measuring a person's writing can act as a surrogate for measuring their thinking.
- b. students' online activity is proportional to their offline thinking.
- c. no posts are lost due to technical difficulties.

- d. each post can be adequately classified
- e. distance and blended students are equally motivated to use the asynchronous online discussion forums.

The first two assumptions are always concerns, no matter what type of assessment is used for written discussion posts because one can never truly know what someone is thinking, only what they choose to reveal. However, writing is considered to be a useful piece of evidence with which to support an investigation of thinking and frequently provides the foundation for scientific investigations on such. There are two different types of content that were examined in this study: manifest content and latent content. Manifest content included the objectively observable characteristics of the text of the transcripts, such as the number of words per message (Heckman & Annabi, 2005; Rourke et al., 2001). Evaluation of the latent content involves inferring information that is not explicitly stated in the text, and thus requires observable behavioural indicators to be present and is more open to subjective interpretation (De Wever et al., 2006; Heckman & Annabi, 2005; Rourke et al., 2001). An example of latent content in this study was indicators of higher order thinking such as integration posts in the discussion forum – while the investigator could not directly observe higher order thinking, behavioural indicators could be observed such as student posts that combined their own ideas and experiences with ideas from other students or the literature. The use of an established coding scheme based on a defined theoretical framework provides help in interpreting latent content and its indicators, and also ensures greater internal validity of the study as there are other studies available for comparison (De Wever et al., 2006).

The assumption that student's online activity is proportional to their offline thinking presents more difficulty. Students only write and post a portion of what they are thinking about, and that proportion will vary from individual to individual and circumstance to circumstance, regardless of whether they are distance or blended students. For instance, some students make a greater effort when working on team projects than they otherwise would, while others do the opposite. Similarly some students may find their voice with the relative time and space to reflect before posting, while others are more comfortable with offline communication. Observations of the

discussion forums and interviews confirmed that considerable thinking, collaborating and writing occurred offline, especially for students in the blended program. In addition, how much of what the students were thinking about was reflected in the discussion forums was influenced by what primary mode of communication was, the assignment directions and possibly the delegation of individual tasks within a subgroup. For instance, distance students posted more often and thus provided more evidence of their collaboration and thinking than blended students did. It also appeared that instructor directives regarding participation in the online discussion forums may also stimulate some form of activity for blended students. Similarly, some tasks within the subgroups may have been more engaging for certain individuals, prompting a greater effort from them.

The assumption that no posts were lost due to technical difficulties, while usually true, didn't always hold. As noted in the Results, the posts for two blended 2009 teams were completely lost due to technical issues. The investigator also occasionally observed messages that indicated that a student was re-posting a message that was "lost". Although the student explicitly stated that they were reposting the information, it doesn't mean the replacement post was identical to the missing post. Additionally, there may have been other instances of lost posts in which the student either didn't repost, or reposted without explicitly noting that there had been a problem. Given the lack of student complaints over time about technical issues either directly to the instructor or in the course evaluations, technical issues did not appear to be a major limitation to this study.

The assumption that the discussion posts could be adequately assigned to one of the Cofl cognitive categories did appear to be upheld. With the modification to the categories to include an organization category, relatively few posts were categorized as "other". This assumption also held true for the CLS and Cofl social presence indicators. Although the indicators used in these coding schemes are not mutually exclusive, they were observed to be in use by both distance and blended students, and they contributed to the investigator's ability to interpret the student's online behaviour. Many of these interpretations were confirmed by the interviews.

The assumption that all the students were equally motivated to use the discussion forums was problematic because of the offline communications that occurred as well as the different meanings of silence in distance and face-to-face communications. Both interviews and content analysis confirmed that face-to-face conversations were used for most of the communication between blended students, and therefore were not captured in the analysis of the discussion forums. Distance students appeared to use the discussion forums as the primary means of communication, resulting in a richer record of their discussions. Another issue is that of students who may have been cognitively engaged but reluctant to post (so called “lurkers”). Such students may be seen as not engaged because their presence and interaction with the team can’t be observed (Hara et al., 2000). Xin and Feenberg (2007) point out that while in face-to-face conversation, silence and continued attention to the speaker indicate comprehension and a desire by the listener for the speaker to continue, in the online environment, silence (lack of posts or responses to posts) may signify agreement, disagreement, lack of engagement or that the individual is completely absent from the discussion forum. Interpreting the online silence of blended students is further complicated because the student may be silent in the online discussion forums but contribute greatly to the face-to-face team discussions. The course requirement for students to post a certain number of messages per case may have made the activities of some students more visible than they otherwise might have been because lurking behaviour without posting would not have earned marks for participating in the discussion. Although not all posts are of good quality, most students who only post once submit a long post complete with citations that usually appears very late in the discussion.

### **Conclusions and Assessment Considerations.**

This section describes the fit of online PBL into the RRU learning and teaching model, and evidence that students are learning more than just content from the online PBL assignment. The conclusions and assessment considerations of this study based on the research questions and the identified literature gaps are then discussed.

Online PBL is a good fit for the RRU LTM. This model emphasizes learning that is outcomes-based; technology-enhanced; experiential; authentic; learning community-

based; team-based; integrative; applied; engaged; action research-focused; supportive; and flexible (Royal Roads University, 2013b). Although not every course at RRU needs to include all of these elements, every course does include some of them, and programs as a whole do include all the elements. The Ecotoxicology course with its online PBL includes most of the elements with the exception of action research. PBL is useful as it highlights the applications while still allowing the instructor to support the learning through just-in-time instruction on the forum for the distance students and instructional support in the classroom for the blended students. PBL is also a good fit for the multidisciplinary RRU BSc programs because it allows students to integrate information from many disciplines into their solutions to the problem. Both distance and blended students incorporated information not only from sources that they found themselves but also information from textbooks and lecture notes from other courses in the program.

PBL was effective in both distance and blended cohorts although the communication methods available changed the timing and substance of what was shared on the discussion forum. The ability of the blended cohorts to meet face-to-face decreases both the appearance of social interactions on the forum and the use of organizational posts. Distance students used the discussion forum for organizational purposes, exchange of ideas, assembly of documents and as the primary communication interface between each other and the instructor. Blended students used the discussion forums in compliance with a course participation requirement, so the discussion forums functioned primarily as a record keeping tool and an area for moderators to pick up portions of text which were ready for integration into the final report.

The online PBL aspect of the course was useful in both the distance and blended formats as it helps students to learn skills beyond just course content. Bob (2010 blended student) summarized the process this way

I think the learning process was very, very interesting and I remember walking out of the Bachelor program and there were a couple of these large projects, especially like this, and thinking "Wow, I learned a lot about myself" in them. It was a very, very interesting learning experience to take away and apply to my career, my life afterwards.

Students have to develop skills in areas such moderation, negotiation of expectations and timelines, research and disciplinary literacy, recognition of knowledge gaps, and knowledge application and critical assessment of source material. The group process of PBL in the cohort context provides social support; a learning community with a common focus, diverse viewpoints to bring perspectives to problem solving, group confidence that they can solve the problem together, and increased motivation as individuals do not want to let the group down.

To better analyze these posts and address the research questions about the approaches taken by teams in the blended and distance classes, a category "organization" was added to the Cofl cognitive presence to capture posts that organize the team and include tasks such as volunteering to research a topic, setting deadlines, or using hard scaffolds from the problem to organize the threads of the discussion. Organization posts were often key to determining what is happening in a team. The utility of the organization indicator for cognitive presence is that it captures student activities in the PBL discussion forum that are similar in function to the design and organization indicator of teaching presence that describes the instructor's role in organizing the curriculum and activities of the course. It seems that this is an indicator of the overlap between cognitive presence and teaching presence for students (see Figure 1). This expansion to the cognitive presence indicators was useful as it allowed for the capture of planning and group organizational steps that require critical thinking but don't necessarily reflect primary course objectives. These steps are critical to the group being able to collaborate by breaking the task down into smaller steps that can be taken by individuals and subgroups, and helping to create templates and action plans for the team. When assessing the critical thinking of individuals participating in the team, these activities should be included. The organization indicator's position at the interface between cognitive presence indicators and teaching presence (see Figure 1) is also useful because it reflects the peer teaching that happens in collaborative learning environments like PBL teams. Such peer-to-peer teaching presence is also evidence that students are trying "to assume increasing responsibility and control of their learning" (Vaughan et al., 2013), which is a goal of PBL in general (Guilar & Loring, 2008; Hmelo-Silver, 2004; Hmelo-Silver et al., 2007) and the RRU LTM (Royal Roads

University, 2013b). The organization indicator helps to illuminate the approach that the team is taking to the discussion, which can be a useful starting point for discussion between the investigator and the team if the team is having difficulties that stem from their approach either to the problem or to the moderation.

This project also involved developing a collaborative behaviour and a learning scaffold coding scheme. Addressing the research questions about how collaboration and scaffolding impact the exhibition of critical thinking in online PBL discussion forums required the development of these coding schemes because the Cofl model doesn't include indicators that could be used to characterize these behaviours. The social interactions of the teams were categorized using the social presence indicators from the Cofl model as described by Garrison et al. (2001) because they were already part of the Cofl model and had been validated (Arbaugh, 2007).

Assessment of the discussion forums will never be as simple as just counting the number of posts made by a team. Assessment requires a content expert both to help students to sort out conceptual confusion and to evaluate whether or not higher order thinking is occurring. Categorizing the posts into the Cofl categories is useful for assessing content; and PBL-CT scores were useful for comparing the relative contributions to the discussion for students within the same cohorts. The PBL-CT score is responsive to variables such as the primary means of team communication, and moderator choices about the use of templates and document assembly occurring on or off of the forum. The PBL-CT score, when taken in context of the team's use of the discussion forum, offers an index of the student's extended engagement with the course content, and reflects critical thinking in a way that is less sensitive to the time pressures and individual pressures than the FE-PBL scores which are based on the final exam. The investigator has since experimented with using PBL-CT scores to grade the critical thinking learning outcome for the course. Preliminary results indicate that the assessment scale (what score is needed for a particular letter grade) may require adjustment between distance and blended cohorts, but that it appears to be a useful assessment within a particular cohort.

The collaboration markers are useful for assessing teamwork, especially for distance students. Assessing scaffold use can help the instructor to assess source

material and to build up reference tools to help support students who are struggling with learning how to do research. Use of the collaboration indicators helps to provide instructors with evidence to support the evaluation of learning outcomes related to collaboration, and can be used with both distance and blended classes that are using asynchronous online discussion groups.

Problem design is important both in terms of designing or selecting problems that are authentic to the field, and have an appropriate level of ill-structuredness and learning scaffolds. The learning scaffolds can be used by students to limit the scope of the problem, to organize their teams, and to improve student confidence in their ability to solve the problem. Careful design of the problem allows scaffolding to be faded over time to encourage students to become the independent self-directed students (again, as is the goal of the RRU LTM). Teaching presence in the form of timely feedback on their final case reports or instructor posts to the discussion forum can be used to establish and reinforce the level of learning required; and allow students to self-determine the requirements when the hard scaffolds in the problems are reduced. This helps encourage the self-direction and independence of students.

Assignment instructions impacted the behaviour of students in the discussion forums. The course requirement to post a minimum number of posts per week did seem to ensure forum activity. Perhaps predictably, when the course outline was changed in 2009 to explicitly note that the penalty for nonparticipation in the online discussion would be a score of zero on the team PBL case report, the posting behaviour by the blended teams became more similar to that of the distance teams. The requirement for moderators to generate a report at the conclusion of the discussion that summarized the discussion and addressed the case problem appeared to motivate students towards posts which used LS and integrated ideas. This is significant because numerous authors (e.g. Garrison et al., 2001; Garrison & Arbaugh, 2007; Meyer, 2003) have noted that discussions can easily stall in the exploration phase. The need to report out on the discussion forum appeared to encourage both the distance and blended students to submit more complex posts ready for integration into the final report - in complete sentences with citations and polished writing.

The availability of Google Docs or similar collaborative writing software will require a change in the method used to assess the online discussion forums. The use of Google Docs requires the instructor to have an invitation to view the collaborative document to achieve the same instructional and assessment goals. With an invitation to view the document, the instructor can access the revision history to view previous versions of the document in order to monitor student activity, and correct misconceptions that are currently achieved by monitoring the discussion forum.

PBL case reports included evidence of offline activities such as questions that were answered in the PBL case report but not on the discussion forum, or documents that were assembled offline and handed in. The blended teams tended to use the discussion forums as a place for the moderator to pick up their finished work. As a result, a lot of the team-work and collaboration that is part of a PBL activity occurs offline for blended teams, which needs to be considered by the instructor when setting expectations for the grading of forum activities.

Both distance and blended teams share similar approaches to PBL with an initial meeting to establish the scope of the problem, generate and distribute an initial list of research needs and negotiate internal deadlines. The moderators appear to be in control of whether the team uses organizational scaffolds or organic discussions on the forums and what type of document assembly is used. Review of feedback on previous cases appears to have been undertaken as an informal process. Both distance and blended teams were successful in completing the PBL problems as determined by the completed case reports being submitted.

### **Where do you go from here?**

Future research directions fall into a few categories. First, more details are needed to build on the observations of this study with regard to the how to best encourage collaborative behaviour; how the student moderators are working; and how to encourage the best practice of this role. A second area for further study is how the team use of Google Docs (or other collaborative authoring software) fits into the PBL activity. The investigator would like to look at the role of time to make decisions and how it impacts the team conflict over deadlines. And finally further work on what literature students are using and what connections they are making between the Ecotoxicology

course and other courses in the program in order to help students to best develop these connections and research skills.

In future, it would be interesting to look at the online activity of the students in the course that precedes Ecotoxicology to look for students who frequently post and display collaborative behaviours even when they are not moderating (especially responding to teammates' posts). If this behaviour is consistent – that is, it is due to the way those students work and not a result of their “role” within a particular team, it might be useful for the instructor to know for the formation of the PBL case discussion teams.

Individuals with strong collaborative behaviour patterns could help model this for others students who are learning moderation skills, as well as support the social structure of the team online. This is particularly important for distance teams who use the asynchronous discussion forums as their primary means of communication.

Another topic for future study might analyze the different kinds of moderators that could be observed in the online discussion groups and how that relates to the success of the group. For example, some moderators respond fairly frequently after posts, some only respond every now and again, and some appear to be sitting in the background but not really doing much online. Are those moderators that are “quieter” less effective or just doing more off the forum where it can't be observed? Xin and Feenberg (2007, p. 416) note that “writing a message that is delivered and accepted encourages further activity in the forum”. It would be of interest to collect more interview data to get some perspective on the role of the student moderators and how their behaviour impacts the team's behaviours.

Further work also needs to be done to evaluate the student contributions that are occurring offline (including in a collaborative creation space like Google Docs) and how it is used alongside the discussion forums. This would require an invitation to the group document but would allow a more comprehensive evaluation of the individual contributions. This is a limitation to the current study as in some cases the discussion forum only indicates that a student changed something on the document without supplying any details on how extensive those changes were. This can also be a problem as the changes that a student makes to the document may have been equivalent to one or many posts in the discussion forum, making comparisons between

teams using Google Docs and those that don't difficult. In future, if the use of Google Docs becomes more prevalent in a given cohort, participation may need to be assessed using the revision history rather than a discussion forum, especially for blended cohorts.

One change that could be made to the assessment for the PBL activity would be to alter the type of PBL to the closed-loop form, which requires students to formally critique their approach to the problem (see Table 1). Although diligent students and teams may already be doing this informally, it is not something that is visible to the instructor. Given that Google Docs may eventually make the discussion forums "busy work" rather than a useful learning tool, moving students to a more formal critique of their approach and solution may be another way to assess how successfully the PBL methodology is applied by teams and individuals.

Unfortunately in this study there were only a few interviewees. In future, it would be interesting to have some interviewees from teams that have the appearance of being very successful functional groups in the online discussion forums, and then ask whether these teams are actually perceived as successful by the participants and why? In a similar way, it would be valuable to know more about what was happening in the offline environment, and how to best encourage those behaviors that seem to be the best at supporting critical thinking regardless of whether that is happening offline or online?

Because blended teams met face-to-face, they were able to come to decisions and delegate tasks more quickly than their distance counterparts. Whether these faster decisions were advantageous beyond the ability to make them quickly is uncertain. For instance, it is possible that with more time to consider factors such as outside obligations, that there might be fewer conflicts within distance teams regarding failures to meet internal team deadlines. It would be interesting to have interviews to ask about this.

The BSc programs as a whole were designed to be multi-disciplinary and allow students to make cross-discipline connections. The results of this study suggest that the Ecotoxicology PBL cases were having the desired impact of encouraging students to think broadly about the problems and apply diverse knowledge to their solution. It might be useful in the future to have separate textbook and lecture notes indicators for each course in the program to evaluate how the PBL problems are interacting with the LS

provided not just by the Ecotoxicology course but those provided by other courses in the program. This may also allow program planning decisions to increase the cross-fertilization of courses to further encourage these connections.

Similarly in the future, it would be interesting to break down the "websites found by students" indicator in more detail. For example, having separate indicators for primary literature, technical literature (e.g. CCME, IRIS, WHMIS), legislative guidelines, etc. The websites found by students indicator in this study demonstrates that students are reading material that wasn't on the required reading list. A future question in this regard may be: is there a difference between the distance and blended students with regard to the type of literature they are consulting? For instance, are the distance students with more work experience consulting more professional/technical/practitioner's literature than the blended students who tend to have less relevant work experience?

The research conducted as part of this dissertation has already impacted the assessment in the Ecotoxicology course. The PBL-CT scores and the collaboration indicators are being used to assess the student posts for both distance and blended students (with the scale to achieve a particular grade adjusted). This provides much more consistent evaluation between members of the same class than simply counting the number of posts. It is hoped that this research will also contribute to the assessment and course design of other courses in the BSc programs at RRU.

### **Final thoughts.**

This dissertation project began as a way to look at the differences that were observed between the distance and blended students and teams during the online PBL portion of the Ecotoxicology course. The expansion of the cognitive presence indicators to include organization helped to analyze the data and to reflect the intersection of cognitive presence and peer-to-peer teaching presence. This study also developed a series of collaboration and learning scaffold indicators that can be meaningful and useful for others seeking to analyse online PBL activities for either research or assessment purposes. Along the way, the research and the teaching practice influenced each other in an iterative way. This seems to be a good example of PBL in practice.

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## **Appendix A Ethical Review Documents**

### **Participant invitation, participant consent forms and interview questions**

#### **Email interview invitation.**

I would like to invite you to be part of a research project that I am conducting. The purpose of this research project is to compare the critical thinking skills of students enrolled in blended and distance undergraduate environmental science programs who are engaged in online problem-based learning. I will also be looking at factors that influence critical thinking, such as learning supports, prior experience, type of questions used, and time, as well as the kinds of tasks that students undertake online and offline. This project is part of the requirement for a Ph.D in Curriculum and Instruction at the University of Victoria. The members of your cohort were chosen as prospective participants because you are part of a recent BSc class in Environmental Science or Environmental Management to complete ENSC 407 Ecotoxicology with the same investigator teaching both cohorts.

If you are interested in learning more about the project and potentially participating in it, please have a look at the attached consent forms for more information about my study, and email me to indicate your interest in participating. I would appreciate hearing from you by the end of the week if you are willing. If you have any questions about the project or would like more information about it, please don't hesitate to contact me via email ([mnoble@uvic.ca](mailto:mnoble@uvic.ca)) or telephone (xxx) xxx-xxxx.

**Participant consent form.**

**Characterization of Critical Thinking Indicators in Problem-Based Learning Online Discussions of Blended and Distance Undergraduate Environmental Science Students using the Community of Inquiry Model**

I am inviting you to participate in my research study entitled *Characterization of Critical Thinking Indicators in Problem-Based Learning Online Discussions of Blended and Distance Undergraduate Environmental Science Students using the Community of Inquiry Model*. This study is being conducted by me, Michael-Anne (Mickie) Noble, a faculty member at Royal Roads University and a Ph. D candidate in the Department of Curriculum and Instruction at the University of Victoria, in partial fulfillment of the requirements of my doctoral degree in Education. You may contact me by telephone at (xxx) xxx - xxxx or email at [mnoable@uvic.ca](mailto:mnoable@uvic.ca) if you have any questions about the study. My graduate supervisor at UVic is Dr. Tim Pelton, who may be contacted by calling (xxx) xxx - xxxx. My supervisor at Royal Roads University is Dr. Matthew Heinz, who may be contacted by calling (xxx) xxx - xxxx. This research project is being partially funded by an Internal Research Grant from Royal Roads University. In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Research Ethics Coordinator, Office of Research at Royal Roads University (250-391-2500 or [ethicalreview@royalroads.ca](mailto:ethicalreview@royalroads.ca)) or the Human Research Ethics Office at the University of Victoria (250-472-4545 or [ethics@uvic.ca](mailto:ethics@uvic.ca)).

**Purpose and Objectives**

The purpose of this research project is to compare the critical thinking skills of students enrolled in blended and distance undergraduate environmental science programs who are engaged in online problem-based learning. I will also be looking at factors that influence critical thinking, such as learning supports, prior experience, type of questions used, and time, as well as the kinds of tasks that students undertake online and offline.

Research of this type is important because problem-based learning in online environments has not been extensively studied, nor have the factors which influence the level of critical thinking shown by students during online problem-based learning discussions. This research will contribute to improving designs for online courses that

include problem-based learning components to better support the development of critical thinking skills.

**How were you selected to participate and what is involved in your participation?**

I am asking you to participate in this study because you are a member of the most recent BSc Environmental Science or Environmental Management cohorts to complete the ENSC 407 Ecotoxicology course with the same investigator. All the members of your cohort that are on the departmental email list are being invited to participate in this study.

I will be examining the online discussion posts made by the cohort as part of ENSC 407 (Ecotoxicology) and making comparisons of critical thinking levels exhibited in the discussion posts between members of the on campus and distance cohorts. I will also be comparing the level of critical thinking observed in the posts, and marks on the scenario portion of the final exam between different cohorts. Marks data will only be reported in the form of cohort aggregates and will not be attributed to individuals. If you agree to voluntarily participate in this research project, I will interview you about your opinions, thoughts and participation in the online discussions of ENSC 407. The purpose of the interview is to help me to understand how the online discussions proceeded for the various groups. As a result, part of the interview may include questions about how your group approached and worked on the discussions or specific posts. I expect the interview to take 20-30 minutes.

The interview may be conducted in person (at RRU or another mutually agreeable location), via telephone or Skype depending on our relative locations and availability. The interviews will be recorded using an electronic data recorder to allow for later transcription. Once your interview has been transcribed, I will send you a copy via email to allow you to verify the information that you provided during the interview, and to allow you to provide any further thoughts that you may wish to add.

**Benefits and Risks of this Research Project:**

There are a number of potential benefits of this research project. I hope that you will feel a sense of satisfaction from contributing to the continual improvement of the BSc programs at Royal Roads University. Because online education is used extensively by RRU, this project will help RRU faculty and staff to design better online courses that

include online problem-based learning components, and better support students in developing critical thinking skills. Your informational legacy will also influence online course design beyond RRU when the results of this study are shared in conference presentations and journal articles. In theory, problem-based learning appears to suit disciplines like environmental science that require interdisciplinary approaches very well, but there is a significant gap in the academic literature in the area of problem-based learning in disciplines outside medicine. I hope that this study will contribute to filling this gap.

Participating in this research does not present any known or anticipated risks to you, as the discussion forums have been archived on the RRU server since your graduation and are no longer accessible to members of the cohort, and your interview responses will be protected through the use of pseudonyms. Participation in this study may cause some minor inconvenience to you, due to the time required for participation, but I hope that you will not find it to be an onerous commitment.

### **Anonymity and Confidentiality**

In order to protect your anonymity, pseudonyms will be used with any example quotes that may be drawn from your posts, and any data associated with marks will only be reported as cohort aggregates.

While your name will not appear in any of the research work, you should be aware that there are limits to the degree to which I can guarantee your anonymity. Royal Roads is a relatively small university whose identity, learning model and course design are critical to the academic credibility of this study. As you are aware, access to the online discussion forums was restricted to the investigators and members of a given team within the class. However, the relatively small size of the cohorts in any given year (30-45 individuals) does mean that there is a very small possibility that members of your team within your cohort may recognize exemplar quotes from the discussion forums in my dissertation or journal articles published based on my dissertation. As a result, I cannot guarantee complete anonymity and confidentiality for participants. However, as noted above, pseudonyms will be used where appropriate, and I will verify the accuracy of the interview transcripts with you prior to analysis in order to protect your privacy. Your privacy will also be protected because the discussion forums will no longer be

available for viewing by the members of the cohort at the time my dissertation becomes available as a public document.

### **Sharing Results**

I anticipate that the results of this study will be shared with others in a variety of forms: in my dissertation; as published journal article(s), book chapter(s), or conference presentations; and possibly through pod casts and RRU faculty presentations such as *Roads to Research*. When it is complete, my dissertation will also become a publically available document that will be available through UVic's D-space. I will be happy to provide you a link to it if you wish when it is complete.

### **Storage and Disposal of Data**

All research notes and data will be stored in a locked office on a password protected computer, and backed up on password protected drive space on the Royal Roads University server system to prevent unauthorized access and protect your confidentiality and the confidentiality of your data. I will be using remote connection to the RRU servers for off- campus access to the data files. Should a research assistant be used to help with transcribing the interview data, this individual will be required to sign a confidentiality agreement. I have also entered into a research agreement with Royal Roads University to further protect access to my research data.

The discussion forums that are the focus of this study are archived on the password protected Royal Roads University Server system, and will remain so for an indefinite period to allow for future program evaluation studies as well as for comparison to future cohorts. Electronic interview data will be maintained for seven years beyond the end of the project and will then be erased by being overwritten.

### **Voluntary Participation**

Your participation in this research project must be completely voluntary. I began recruiting participants for this study after your BSc program was complete to avoid a conflict of interest caused by my dual role as your investigator and a researcher; and so that you would not feel pressured to participate in my research study.

If you do decide to participate, you may withdraw at any time up to one week following your receipt of the interview transcript without any consequences or any explanation. If you do withdraw from the study your interview data will be removed from the interview

response data set and will be destroyed by overwriting the electronic file. The discussion posts made while you were a student in ENSC 407 will still be analyzed because analysis of the online discussion process cannot proceed if posts are removed from the group forum, but I will only report on your posts as part of a class aggregate, and no example quotes will be used from your posts. It is not possible to remove this data from the archived files on the RRU server.

If you agree to participate in the interview, you will be asked to verify your willingness to continue to participate in the study by acknowledging the receipt of the interview transcript and its accuracy.

Your signature below indicates that you understand the above conditions of participation in this study, that you have had the opportunity to have me answer your questions about the study and that you agree to participate in this research project.

*PLEASE SELECT STATEMENT only if you agree:*

- I agree to be contacted for an interview: \_\_\_\_\_ (Participant to provide initials)
- I would prefer a face-to-face interview: \_\_\_\_\_ (Participant to provide initials)

at \_\_\_\_\_ (please indicate the preferred location)

- I would prefer a telephone interview: \_\_\_\_\_ (Participant to provide initials)
- I would prefer a Skype interview: \_\_\_\_\_ (Participant to provide initials)

- I agree to have my interview responses used as quotes with a pseudonym to protect my privacy: \_\_\_\_\_ (Participant to provide initials)
- I agree to have my online discussion responses used as quotes with a pseudonym to protect my privacy: \_\_\_\_\_ (Participant to provide initials)
- I agree to have my marks for the scenario portion of the final exam of ENSC 407 used in the analysis and reported as cohort aggregates only. I understand that marks data will not be attributed in any way to individual students:  
\_\_\_\_\_(Participant to provide initials).
- I would like to be provided with a link to the final dissertation when it becomes available on D-space. \_\_\_\_\_(Participant to provide initials).

\_\_\_\_\_  
*Name of Participant (Please  
print)*

\_\_\_\_\_  
*Signature*

\_\_\_\_\_  
*Date*

***A copy of this consent will be left with you, and a copy will be taken by the researcher.***

**Interview questions.**

1. How many years of work experience did you have before starting your BSc program?
  - a. Tell me about the kinds of work experience you had before starting the program?
  - b. Which of these experiences did you find the most useful when working on the case studies? Why?
  
2. How comfortable are you in the online environment? (in general and for doing this type of asynchronous discussion assignment).
  - a. What difficulties did you find with being online for this assignment?
  - b. What advantages did you find with being online for this assignment?
  - c. What influenced your decisions about what/when to post?
  
3. Various materials were provided to help you work on the case studies (e.g. lecture notes, websites, textbooks, guiding prompts/questions). Can you tell me which if any of these that you used?
  - a. Why those particular materials?
  - b. How much did you use them?
  - c. When in the process did you use them?
  - d. What other resources did you use? How did you find out about them?
  - e. Did you find discussions with others were important in clarifying ideas? If so, with whom?
  
4. Tell me about how your team approached the case study as each new problem came out?
  - a. How did your team decide what needed to be done?
  - b. Did your team's approach change as you moved from case 1 to 4? Why or why not?

- c. Did your group meet offline in some form? What activities were taking place offline for your team? Who was leading these activities? Were they effective for helping you to think about the assignment? Why or why not?
  
5. Who on your team do you think displayed the most critical thinking skills? Why?
  - a. Who in your group was most helpful to your understanding of the assignments?
  - b. Who did you help most in understanding the assignments?
  - c. What did you do to help them?
  
6. Looking at this example (show example) from your group's discussion, can you tell me what you were thinking about when this occurred?
  - a. When it was your turn to moderate, how did you approach the task?
  - b. What did you do differently when it was your turn to moderate as compared to when it was not?

## University of Victoria certificate of ethical approval



University  
of Victoria

Office of Research Services | Human Research Ethics Board  
Administrative Services Building Rm B202 PO Box 1700 STN CSC Victoria BC V8W 2Y2 Canada  
T 250-472-4545 | F 250-721-8960 | uvic.ca/research | ethics@uvic.ca

### Certificate of Renewed Approval

PRINCIPAL INVESTIGATOR: <b>Michael-Anne Noble</b>	<b>ETHICS PROTOCOL NUMBER</b> <b>11-539</b> Minimal Risk Review - Delegated
UVic STATUS: <b>Ph.D. Student</b>	ORIGINAL APPROVAL DATE: 22-Dec-11
UVic DEPARTMENT: <b>EDCI</b>	RENEWED ON: 16-Nov-15
SUPERVISOR: <b>Dr. Tim Pelton</b>	APPROVAL EXPIRY DATE: 21-Dec-16
<p><b>PROJECT TITLE: Characterization of Critical Thinking Indicators in Problem-Based Learning Online Discussion of Blended and Distance Undergraduate Environmental Science Students Using the Community of</b></p> <p>RESEARCH TEAM MEMBER None</p> <p>DECLARED PROJECT FUNDING: Royal Roads University Internal Research Grant (2011)</p>	
<b>CONDITIONS OF APPROVAL</b>	
<p>This Certificate of Approval is valid for the above term provided there is no change in the protocol.</p> <p><b>Modifications</b> To make any changes to the approved research procedures in your study, please submit a "Request for Modification" form. You must receive ethics approval before proceeding with your modified protocol.</p> <p><b>Renewals</b> Your ethics approval must be current for the period during which you are recruiting participants or collecting data. To renew your protocol, please submit a "Request for Renewal" form before the expiry date on your certificate. You will be sent an emailed reminder prompting you to renew your protocol about six weeks before your expiry date.</p> <p><b>Project Closures</b> When you have completed all data collection activities and will have no further contact with participants, please notify the Human Research Ethics Board by submitting a "Notice of Project Completion" form.</p>	
<b>Certification</b>	
<p>This certifies that the UVic Human Research Ethics Board has examined this research protocol and concluded that, in all respects, the proposed research meets the appropriate standards of ethics as outlined by the University of Victoria Research Regulations Involving Human Participants.</p> <div style="text-align: center;">  <p>Dr. Rachael Scarth Associate Vice-President Research Operations</p> </div>	

Certificate Issued On: 16-Nov-15

11-539

Noble, Michael-Anne

## RRU Privacy Research Agreement Letter and Confirmation of TCPS (2010) Section 3.7 Exemption



ROYAL ROADS  
UNIVERSITY



Office of Research

8 December, 2011

Mickie Noble  
SES Director  
School of Environment and Sustainability – Faculty  
Royal Roads University  
2005 Sooke Road  
Victoria, BC V9B 5Y2

Dear Mickie,

Please find attached a Privacy Research Agreement with Royal Roads University.

This agreement confirms that clearance is given to you to access data for your proposed research "Characterization of Critical Thinking Indicators in Problem-Based Learning Online Discussions of Blended and Distance Undergraduate Environmental Science Students using the Community of Inquiry Model".


This letter is our confirmation that clearance has been give for TCPS (2010) section 3.7

Article 3.7 The REB may approve research without requiring that the researcher obtain the participant's consent in accordance with Articles 3.1 to 3.5 where the REB is satisfied, and documents, that all of the following apply:

- (a) the research involves no more than minimal risk to the participants;
- (b) the lack of the participant's consent is unlikely to adversely affect the welfare of the participant;
- (c) it is impossible or impracticable to carry out the research and to answer the research question properly, given the research design, if the prior consent of the participant is required;
- (d) whenever possible and appropriate, after participation, or at a later time during the study, participants will be debriefed and provided with additional pertinent information in accordance with Articles 3.2 and 3.4, at which point they will have the opportunity to refuse consent in accordance with Article 3.1; and
- (e) the research does not involve a therapeutic intervention, or other clinical or diagnostic interventions.

Should you require any additional information, please feel free to contact us.

Sincerely,

  
Mary Bernard  
Associate Vice President Research  
Office of Research  
Royal Roads University  
Email: [mary.bernard@royalroads.ca](mailto:mary.bernard@royalroads.ca)

**RRU certificate of study ethical approval**

18 April, 2017

Mickie Noble  
Assistant Professor  
Chair, Undergraduate Program Committee  
School of Environment and Sustainability  
Royal Roads University  
2005 Sooke Road,  
Victoria, BC Canada V9B 5Y2

Dear Mickie,

Please accept this letter as confirmation that the Royal Roads University Research Ethics Board (RRU REB) has given clearance for the research project "Characterization of Critical Thinking Indicators in Problem-Based Learning Online Discussions".

This letter is to confirm that clearance was granted on 20 January, 2012, pending any additional clearances required by the sponsoring organization or any other organization.

Should you require any additional information, please feel free to contact us.

Sincerely,

A black rectangular box redacting the signature of Colleen Hoppins.

Colleen Hoppins  
Research Ethics Coordinator

## Appendix B Statistical Tables

Table B1 *Fisher's Least Significant Difference Test for ANOVA Analysis of the FE-PBL Scores for Four Cohorts of Distance BSc Students During an Ecotoxicology Course*

(I) Cohort	(J) Cohort	Mean Difference (I-J)	<i>p</i>
2004 cohort	2006 cohort	10.53*	0.004
	2008 cohort	14.46*	0.000
	2010 cohort	12.38*	0.000
2006 cohort	2008 cohort	3.92	0.235
	2010 cohort	1.85	0.566
2008 cohort	2010 cohort	-2.08	0.486

\* The mean difference is significant at the 0.05 level.

Table B2 *Fisher's Least Significant Difference Test for ANOVA Analysis of the FE-PBL Score for Four Cohorts of Blended BSc Students During an Ecotoxicology Course*

(I) cohort membership	(J) cohort membership	Mean Difference	
		(I-J)	<i>p</i>
2004 cohort	2006 cohort	7.42*	0.007
	2009 cohort	13.87*	0.000
	2010 cohort	6.43*	0.016
2006 cohort	2009 cohort	6.44*	0.022
	2010 cohort	-0.99	0.685
2009 cohort	2010 cohort	-7.44*	0.007

\* The mean difference is significant at the 0.05 level.

Table B3 *Fisher's Least Significant Difference Test for ANOVA Analysis of the Mean PBL-CT Scores for Four Cohorts of Blended BSc Students in an Online PBL Activity During an Ecotoxicology Course*

(I) cohort membership	(J) cohort membership	Mean Difference	
		(I-J)	<i>p</i>
2004 cohort	2006 cohort	2.98	0.100
	2009 cohort	-13.32*	0.000
	2010 cohort	-15.09*	0.000
2006 cohort	2009 cohort	-16.30*	0.000
	2010 cohort	-18.07*	0.000
2009 cohort	2010 cohort	-1.77	0.324

\* The mean difference is significant at the 0.05 level.

Table B4 *Descriptive Statistics for FE-PBL Scores for Distance and Blended BSc Students During an Ecotoxicology Course*

Program enrolled	<i>N</i>	Mean	Std. Deviation
Distance	108	80.59	12.80
Blended	144	81.10	12.01

Table B5 *Correlation Analysis of FE-PBL and PBL-CT scores for Distance and Blended BSc Students in an Online PBL Activity During an Ecotoxicology Course*

		FE-PBL score	PBL-CT score
FE-PBL score (all cohorts)	Pearson Correlation	1	0.072
	<i>p</i> (2-tailed)		0.256
	<i>N</i>	252	252
FE-PBL score (distance, 2009 blended 2010 blended)	Pearson Correlation	1	0.186
	<i>p</i> (2-tailed)		0.012
	<i>N</i>	182	182

*Table B6 Descriptive Statistics for Counts of Cognitive Community of Inquiry Indicators for Distance and Blended BSc Teams Per Case in an Online PBL Activity During an Ecotoxicology Course*

	Program	<i>N</i>	Mean	Std. Deviation
Organization	Distance	60	65.17	24.63
	Blended	76	10.16	7.64
Triggering	Distance	60	0.55	0.77
	Blended	76	0.63	1.13
Exploration	Distance	60	31.02	16.75
	Blended	76	19.55	15.25
Integration	Distance	60	25.58	11.80
	Blended	76	14.80	9.53
Resolution	Distance	60	4.47	2.67
	Blended	76	1.62	2.000
Other	Distance	60	11.77	6.37
	Blended	76	1.54	3.05

Table B7 *Levene Test for Equality of Variances for PBL-CT Scores Across Four Cases for Four Cohorts of Distance BSc Students in an Online PBL Activity During an Ecotoxicology Course*

	Levene Statistic	df1	df2	<i>p</i>
Case 1	0.839	3	104	0.475
Case 2	4.041	3	104	0.009
Case 3	0.431	3	104	0.731
Case 4	0.501	3	104	0.682

Table B8 *Levene Test for Equality of Variances for PBL-CT Scores Across Four Cases for Four Cohorts of Blended BSc Students in an Online PBL Activity During an Ecotoxicology Course*

	Levene Statistic	df1	df2	Sig.
Case 1	4.078	3	140	0.008
Case 2	1.808	3	140	0.149
Case 3	8.722	3	140	0.000
Case 4	6.538	3	140	0.000

Table B9 Pearson Correlation Analysis of Collaboration Indicators for Distance and Blended BSc Students in an Online PBL Activity During an Ecotoxicology Course

		Moderator	Document Assembly	Ask Questions	Informing the Team	Availability/Timeline	Topic Signup/Plan Agreement	Use Scaffolds	Answer Questions	Share References	Request Direction/Feedback	Directional	Meeting Organizers	Meeting Notes	Multi-Author Messages
Moderator	<i>r</i>	1	0.693**	0.744**	0.737**	0.762**	0.720**	0.351**	0.717**	0.541**	0.591**	0.499**	0.358**	0.084	0.141
	<i>p</i>		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.331	0.101
Document Assembly	<i>r</i>		1	0.828**	0.844**	0.748**	0.778**	0.323**	0.812**	0.420**	0.436**	0.379**	0.210*	0.058	0.057
	<i>p</i>			0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.014	0.502	0.507
Ask Questions	<i>r</i>			1	0.809**	0.771**	0.841**	0.213*	0.883**	0.544**	0.412**	0.475**	0.365**	0.101	0.109
	<i>p</i>				0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.241	0.204
Informing the Team	<i>r</i>				1	0.833**	0.798**	0.322**	0.815**	0.435**	0.506**	0.567**	0.297**	0.002	0.097
	<i>p</i>					0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.977	0.260
Availability/Timeline	<i>r</i>					1	0.805**	0.236**	0.768**	0.435**	0.455**	0.523**	0.277**	-0.031	0.039
	<i>p</i>						0.000	0.005	0.000	0.000	0.000	0.000	0.001	0.720	0.654
Topic Signup/Plan Agreement	<i>r</i>						1	0.265**	0.777**	0.481**	0.437**	0.483**	0.314**	0.081	0.016
	<i>p</i>							0.002	0.000	0.000	0.000	0.000	0.000	0.348	0.851
Use Scaffolds	<i>r</i>							1	0.218*	0.147	0.101	0.151	0.164	0.119	0.218*
	<i>p</i>								0.011	0.087	0.240	0.079	0.055	0.166	0.011
Answer Questions	<i>r</i>								1	0.414**	0.477**	0.506**	0.284**	0.042	0.075
	<i>p</i>									0.000	0.000	0.000	0.001	0.622	0.384

		Moderator	Document Assembly	Ask Questions	Informing the Team	Availability/ Timeline	Topic Signup/ Plan Agreemen t	Use Scaffolds	Answer Questions	Share References	Request Direction/ Feedback	Directional	Meeting Organizers	Meeting Notes	Multi-Author Messages	
Share	<i>r</i>									1	0.384**	0.219*	0.249**	0.095	0.063	
References	<i>p</i>										0.000	0.010	0.003	0.271	0.462	
Request	<i>r</i>										1	0.427**	0.185*	0.024	-0.004	
Direction/ Feedback	<i>p</i>											0.000	0.030	0.784	0.959	
Directional	<i>r</i>											1	0.141	0-0.023	0.052	
	<i>p</i>												0.101	0.792	0.543	
Meeting Organizers	<i>r</i>												1	0.360**	0.293**	
	<i>p</i>													0.000	0.001	
Meeting Notes	<i>r</i>													1	0.033	
	<i>p</i>														0.704	
Multi-Author Messages	<i>r</i>															1
	<i>p</i>															

$N=137$  for all correlations.

\*correlation is significant at the  $p < 0.05$  level (2 tailed)

\*\*correlation is significant at the  $p < 0.01$  level (2 tailed)

Table B10 *Independent t-Tests of Collaboration Behaviours Scores Per Case for Distance and Blended BSc Students in an Online PBL Activity During an Ecotoxicology Course*

	<i>t</i>	<i>df</i>	<i>p</i> (2-tailed)
Answer Questions	-11.51	59.31	0.000
Ask questions	-12.08	59.96	0.000
Availability/timeline	-16.99	60.71	0.000
Directional	-5.46	67.20	0.000
Document assembly	-14.45	62.19	0.000
Informing the team	-14.68	66.16	0.000
Meeting notes	-0.18	134	0.860
Meeting organizers	-2.70	80.79	0.008
Moderator	-10.22	67.19	0.000
Multi-author messages	0.72	134	0.474
Request direction/feedback	-5.88	69.55	0.000
Share references	-4.26	86.38	0.000
Topic signup/plan agreement	-14.76	63.28	0.000
Use templates	-2.58	134	0.011

Table B11 *Independent Samples t-Tests of Investigator and Group Organization Learning Scaffolds Observed In Use for Distance Versus Blended BSc Teams Per Case in an Online PBL Activity During an Ecotoxicology Course*

	<i>t</i>	<i>df</i>	<i>p</i>
Investigator posts	-9.640	60.78	0.000
Action plans	-6.582	69.49	0.000
Templates	-1.647	134	0.102
Posting investigator information	-1.774	103.93	0.079
Signup sheets	-3.502	61.982	0.001

Table B12 *Independent Samples t-test of the Cited Source Material for Distance and Blended Students During an Online PBL Activity in an Ecotoxicology Course*

	<i>t</i>	<i>df</i>	<i>p</i> (2-tailed)
Websites found by students	1.35	133.92	0.179
Textbook	-1.04	134	0.302
Websites from course	-1.84	107.26	0.069
Lecture notes	2.01	134	0.046
Work experience	-5.28	59.14	0.000

Table B13 *Independent Samples t-test of the Source Material Learning Scaffolds for Distance 2004 Cohort and Blended 2004 Cohort Students During an Online PBL Activity in an Ecotoxicology Course*

	<i>t</i>	<i>df</i>	<i>p</i> (2-tailed)
Websites found by students	-1.08	26	0.292
Textbooks	-2.16	12.20	0.051
Websites from course or case	-1.20	26	0.240
Lecture notes	2.25	26	0.033
Work experience	-2.40	11.16	0.035

Table B14 *Independent Samples t-Tests of Social Presence Scores Per Case for Distance and Blended BSc Students in an Online PBL Activity During an Ecotoxicology Course*

	<i>t</i>	<i>df</i>	<i>p</i> (2-tailed)
Affective	-9.29	60.66	0.000
Cohesion	-12.83	70.75	0.000
Open	-1.08	84.09	0.285

Table B15 *Descriptive Statistics for the Correlation Analysis of Two Collaboration Categories (Moderator and Ask Questions) with a Social Indicator Category (Cohesive)*

	Mean	Std. Deviation	<i>N</i>
Moderator	10.63	12.368	136
Ask Questions	8.88	12.559	136
Cohesive	21.63	21.070	136

## Appendix C

### BSc Program Competencies and Learning Outcomes

- 1 Mastery of Background and Key Fundamental Concepts
- 2 Communication, teamwork and personal qualities
- 3 The language, concepts, models and techniques of science and management
- 4 Data collection techniques
- 5 Critical thinking/Problem Solving
- 6 Global Awareness

		ENVMGMT- BSC	ENVSCNC- BSC
<b>1. Mastery of Background and Key Fundamental Concepts</b>			
1.01	Demonstrates broad level of skills and knowledge in written communication and English.	✓	✓
1.02	Demonstrates broad level of skills and knowledge in algebra, geometry, calculus, and statistics.	✓	✓
1.03	Demonstrates broad level of skills and knowledge in basic principles of chemistry.	✓	✓
1.04	Demonstrates broad level of skills and knowledge in cellular biology, biochemistry, physiology and ecology.	✓	✓
<b>2. Communication, teamwork and personal qualities</b>			
2.01	Produce written material.	✓	✓
2.02	Take part in discussions and make presentations.	✓	✓
2.03	Perform effectively as a team member in a variety of situations and circumstances.	✓	✓
2.04	Work with, encourage and help others.		✓
<b>3. The language, concepts, models and techniques of science and management</b>			
3.01	Understand, select and use appropriate statistical techniques.	✓	✓
3.02	Describe the evolution and elements of environmental management tools.	✓	✓
3.03	Describe the structure and function of the atmosphere and hydrosphere.	✓	✓
3.04	Describe the development of environmental statutes and regulations and the linkages between them .	✓	✓
3.05	Explain the processes used in selected primary and secondary industries.	✓	✓
3.06	Describe the fundamentals of surface and groundwater movement.	✓	✓
3.07	Explain the fundamentals of chemistry as they apply to our natural environment.	✓	✓
3.08	Describe the concepts and principles of economics.	✓	✓

3.09	Describe the concepts and principles of land use planning and their application to coastal zone management.	✓	✓
3.10	Describe the structure, form and evolution of natural landscapes.	✓	✓
3.11	Explain the fundamental principles of microbiology and biochemistry.	✓	✓
3.12	Describe and evaluate ecotoxicological principles and tools.	✓	✓
3.13	Describe ecosystems, their underlying structural and functional components, and their response to stressors.	✓	✓
3.14	Describe the fundamentals of entrepreneurship and business decision making.	✓	✓
3.15	Formulate and defend a moral argument or code of ethics.	✓	✓
3.16	Describe the fundamental principles guiding water and wastewater treatment and handling.	✓	✓
3.17	Describe the fundamental principles guiding air quality management and the issues which surround it.	✓	✓
3.18	Explain how leadership, management style, and process, contribute to effective supervision and management.	✓	
3.19	Describe the purpose of public policy, how it is created, and how a multiplicity of competing issues shape its implementation.	✓	
3.20	Explain decision-making processes and how a variety of decision-support tools contribute to more effective outcomes.	✓	
4. Data collection techniques			
4.01	Collect meteorological data for analysis.	✓	✓
4.02	Collect data for hydrological analysis.	✓	✓
4.03	Sample collection and analysis of chemical samples.	✓	✓
4.04	Collect soil data for physical and taxonomic classification.	✓	✓
4.05	Collect microbiological data.	✓	✓
5. Critical thinking/Problem Solving			
5.01	Select and use information and data to critically assess a situation or problem and identify possible actions.	✓	✓
5.02	Creatively analyze and interpret issue scenarios and recommend solutions.	✓	✓
5.03	Plan, implement and monitor appropriate strategies to monitor the problem.		✓
6. Global Awareness			
6.01	Assess the potential impact of human activity on the environment and how it may be lessened or eliminated.	✓	✓

6.02	Describe the principal values that affect sustainability.	✓	✓
6.03	Identify and analyze sustainable development issues.		✓
6.04	Identify the principal barriers to sustainability and propose and defend solutions.	✓	