

**Creating a Competency Continuum:
Assessing mathematical literacy in secondary education**

by

Andrew MacLean

Bachelor of Science in Forensic Science, Trent University, 2010

Post-Degree Diploma in Secondary Education, University of Victoria, 2019

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Abstract

Following educational trends in jurisdictions around the world, in 2015 the Ministry of Education (MOE) in British Columbia (BC), Canada introduced a redesigned K-12 curriculum which moved away from content-focussed educational objectives towards competency-driven learning outcomes. One of the significant challenges of this curriculum change is the absence of a framework that supports educators in effectively assessing the type of learner competency development used by the MOE as part of their graduation framework at the secondary level. In this project, we responded to this challenge by developing and testing a novel assessment instrument for use in a competency-based learning environment in BC. This instrument incorporates fuzzy logic principles to assess learning artifacts in the context of mathematical literacy as defined by the Organization for Economic Co-operation and Development (OECD) Programme for International Student Assessment (PISA). In partnership with the Pacific School of Innovation and Inquiry (PSII), an independent, inquiry-based secondary school located in Victoria, BC, we introduced this assessment instrument, and then, over the course of two months in 2018, collected data concerning its use in assessment of mathematical literacy in their highly personalized and interdisciplinary learning environment. We present the initial findings from the study, and iterations on the assessment tool which further address challenges of implementing competency-based assessment (CBA) in BC K-12 classrooms and beyond.

Keywords: mathematical literacy, competency, assessment, portfolios, secondary school

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Secondly, I would like to acknowledge my wife, Emily Harding, for her incredible support over the past 6 years as I pursued what, at many points, must have seemed like a never-ending journey. For all of those essays you read, presentations you listened to, feedback you gave, and space you provided, know that I am incredibly grateful, and how lucky I feel to have had such a wonderful partner through both this educational journey, and through life.

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Chapter 1: Introduction

Numbers are all around us. We use them to cook food, to buy clothing, to play music, and to build software; and yet for most students in the North American K-12 education system, their formative experiences with mathematics—the academic subject most often correlated with numeracy—are ones of “number-numbness”, with instructional and assessment practices in mathematics marked by “rote calculations, drill and practice ad nauseum” and “endless reams of worksheets” (Monchinski, 2008, p.142). For mathematics educators, the use of this tried and tested methodology is a common and understandable choice (Walls, 2005; Watt, 2005), as they carefully balance the needs and management of a diverse classroom of learners with their own time and resources (Ransom & Manning, 2003). For students, however, particularly for those who struggle to grasp the concepts presented in this manner, this pedagogical paradigm presents significant challenges for both their present and future success, with poor assessment results in early math experiences linked to reduced confidence and low mathematical self-efficacy moving forward in their academic and professional careers (Aarnos & Perkkilä, 2012).

Faced with a world where an understanding of the fundamental processes of mathematics is not only an important part of our day-to-day lives (Ojose, 2011), but also of employment related roles and responsibilities, such limited educational practices have the potential to severely restrict student opportunities post-graduation, particularly when it comes to the growing number of Science, Technology, Engineering and Math (STEM) related careers (Bleyer et al., 1981; Scarpello, 2005). Considering the significant impact this topic has on student success, there seems now—more than ever—a necessity to revisit how learners are supported concerning their development of mathematical literacy. Without a significant shift in the collective mindset of

what it means to be mathematically literate, the education system risks further alienating students with an inaccurate view of the connections of mathematics to the real world; negatively impacting their future in this new STEM focussed economy (Williams, 2015).

In response to this growing recognition of a need to revisit core aspects of mathematics pedagogy in K-12 learning environments, this project seeks to explore the topic of mathematical literacy through the lens of competency assessment, as initiated by a research proposal by the Pacific School of Innovation and Inquiry (PSII), an inquiry-based high-school in Victoria, British Columbia (BC), Canada (see Appendix A). Through a detailed analysis of the academic literature, and supported by results from an exploratory case study which took place at PSII in 2018, this project endeavours to demonstrate the potential impact of a new type of competency assessment model within secondary education, allowing for an authentic evaluation of mathematical competency in a highly-personalized and interdisciplinary learning environment.

Personal Interest

As an educator working for more than a decade in non-traditional learning environments, I have seen first-hand the incredible learner growth that takes place both inside and outside of a classroom. Through organizations such as the Canadian Cadet Program, Boys and Girls Clubs of Canada, HighTechU, and Actua Canada, I have even observed learners demonstrating a practical understanding of advanced topics ranging from principles of leadership to aeronautical and software engineering. Canadian educational policy makers have also recently begun to recognize the value of this type of non-traditional learning, and of a more broad interpretation of where learning environments exist, implementing prior learning assessment and recognition (PLAR) programs in both secondary and post-secondary graduation programs across the country

(Government of Ontario, n.d.; Government of Alberta, n.d.). These PLAR programs provide a means for learners to demonstrate the applicable knowledge and skills they have acquired “in both formal and informal ways, outside secondary school” (Government of Ontario, n.d.).

Despite the wide availability of these alternative learning and assessment pathways for learners, much of the credit-bearing summative assessment practices currently found in K-12 classrooms have remained relatively unchanged. Summative assessment in secondary mathematics classrooms, for example, continues to be dominated by pencil-and-paper tests, even while alternative assessment tools—such as projects and portfolios—are used for lower-stakes formative assessment in those same learning environments (Suurtamm et al., 2010).

It is this contradiction between classroom practice and assessment theory, which was one of the key factors that initially drew me to explore the area of mathematical competency assessment in the context of PSII’s research proposal. Recognizing the role of mathematics as a core academic subject for all BC K-12 learners, and one with increasing importance in various aspects of life progression, I was curious to understand how educators might effectively incorporate these types of innovative assessment practices to not just guide student development in mathematics, but also report on relevant graduation requirements within the BC curriculum.

Relevance in the Context of Modern Educational Reform

Although public education is often described as existing within a broken system (Schank, 2016), the late 20th and early 21st centuries have been marked by a growing debate, particularly in academia, around the need for reform of instructional and assessment practices. In recent years prominent Canadian curricular scholars have even called for a fundamental reconceptualization of the field as whole (Pinar, 2018). While these reform movements have had widespread

implications on the work of educators, when exploring the topic of competency assessment in a learning environment like PSII, two pedagogical shifts in particular come to the forefront: the move towards interdisciplinary and transdisciplinary learning in the classroom (Flogie & Aberšek, 2015), and the accompanying adoption of competency-based curriculum in public and private K-12 school systems around the world (Byrne et al., 2013a; Komba & Mwandaji, 2015; M'mboga Akala, 2021; Sadeq et al., 2020).

Originally theorized by Swiss psychologist Jean Piaget (Bernstein, 2015), the concept of transdisciplinarity in education emerged during the rapid globalization of the world in the 1970s. This (at the time) novel educational approach dissolved the imaginary separation between disciplines and subject areas, instead organizing “teaching and learning around the construction of meaning in the context of real-world problems or themes” (International Bureau of Education, n.d.). With a move towards education that transcends traditional curricular boundaries, there was an equivalent need identified for a change in how this new type of learning might be assessed (Pettersen & Braeken, 2017). This perhaps explains a parallel movement, particularly in post-secondary contexts, around the same time, towards outcome-based learning.

Described by preeminent educational psychologist William Spady as a pedagogy “defined by the successful demonstrations of learning sought from each student” (Spady, 1994, p. 191), one outcome-based approach that became increasingly popular within educational contexts during the 1970s was competency-based education (CBE). With a focus on the use of instructional and assessment practices that support the development of *mastery*, at the core of CBE was the *demonstration* of “knowledge, attitudes, values, skills, and behaviors” (Gervais, 2016, p. 99) required for a learner to be assessed as competent in a given context.

While this concept of using interdisciplinary, competency-based curriculum has continued to gain traction amongst modern educational scholars and practitioners well into the 21st century (Sengupta et al., 2019), a lack of clarity around practical definitions of CBE (Spady, 1997), and a corresponding lack of standardized assessment frameworks continue to be major challenges to the successful integration of these types of innovative pedagogies in the K-12 classroom (Lawrence, 2010; Mansilla & Duraising, 2007). Furthermore, there is growing evidence of how instructional and assessment practices in jurisdictions that have implemented CBE are often misaligned with this new educational paradigm (Komba & Mwandaji, 2015; Sadeq et al., 2020)

Though certainly presenting interesting research questions for educational scholars, for Canadian classroom teachers these on-going challenges present an imminent practical handicap, with K-12 curriculum documents from BC to Nova Scotia having now officially adopted language around curricular integrations and competencies (Government of British Columbia, n.d.; Council of Atlantic Ministers of Education and Training, n.d.). With this in mind, there is a growing need in the educational ecosystem for an innovative framework that can support learners in the competency development process, while also supporting educators responsible for reporting on that development amidst the demanding requirements of classroom teaching.

Research Questions

Through a detailed analysis of the academic literature, and supported by an exploratory case study that examined the implementation of competency-based assessment (CBA) in a K-12 environment, this project seeks to explore the development of such an innovative assessment

framework. With a focus on mathematical literacy, the following chapters examine four interrelated questions regarding CBA in secondary education. Specifically:

1. How can the assessment process in a highly-personalized and interdisciplinary K-12 learning environment be adjusted to incorporate competencies more efficiently?
2. What are the established best practices for assessment in competency-based education?
3. Are portfolios effective assessment tools for use in competency-based education?
4. What is an appropriate framework to assess mathematical competency?

Definitions

Based on the aforementioned research questions and the related PSII proposal, three terms were identified as holding particular importance for this project: *competency-based education*, *educational portfolios*, and *mathematical literacy*. While multiple interpretations of these respective terms were identified in the literature, the definitions below provide an overview of how each of them can be conceptually understood in the context of this research:

Competency-Based Education. While there are varying definitions of competency based education (CBE), for the purpose of this research, competency-based education is considered “an outcome-based approach to education that incorporates modes of instructional delivery and assessment efforts designed to evaluate mastery of learning by students through their demonstration of the knowledge, attitudes, values, skills, and behaviors required for the degree sought” (Gervais, 2016, p. 99).

Educational Portfolios. For the purpose of this research, a portfolio is defined as “a composition of work that a learner [*or educator*] has selected and collected to show

knowledge, skills or competencies, and includes the reflections of the learner on the selected and collected work” (Joosten-Ten Brinke et al., 2008, p. 57).

Mathematical Literacy. For the purposes of this research, *mathematical literacy* is used interchangeably with *mathematical competency* and is defined as stated in the Organization for Economic Cooperation and Development (OECD) Programme for International Student Assessment (PISA) 2015 Mathematics Framework as “an individual’s capacity to formulate, employ and interpret mathematics in a variety of contexts” (OECD, 2017, p. 15).

Research Roadmap

In the following chapters, each of the three main stages of this research project are introduced in detail, beginning with Chapter 2 which provides an overview of the exploratory case study which took place at PSII in 2018. This overview includes a discussion of the proposal that initiated this research, an exploration of the study design, creation of the novel assessment instrument, and initial findings from the study. With a brief review of relevant academic research introduced as part of this inaugural chapter, Chapter 3 provides a more thorough review of the literature, examining 20 empirical research articles on CBA of mathematical literacy, in an attempt to gain perspective on the results from the PSII study. Building on the findings from the case study and literature review, Chapter 4 provides an overview of the iterative development process of the assessment tool which took place between 2018-2021. We conclude with Chapter 5 providing a summary of findings concerning the four main research questions, along with a brief reflection on learning from this project and recommendations for future research.

Chapter 2: PSII Exploratory Case Study

Over the past decade, there has been a growing movement within Canadian K-12 education systems towards a more holistic pedagogical approach in primary and secondary classrooms. Rather than compartmentalizing content into specific subject areas (e.g., Science, English, Fine Arts, Mathematics), teachers and administrators have begun to recognize the value of leveraging the multidisciplinary nature between academic subjects, and the importance of identifying the overarching competencies that are necessary for learners' success both inside and outside of the school environment (Soland et al., 2013; You, 2017). For many secondary schools across the province of BC—and indeed the world—this paradigm shift has come only with recent changes to government-mandated curriculum, with countries from the United States to Kenya having implemented this new type of interdisciplinary CBE as part of ongoing educational reforms (M'mboga Akala, 2021). There are, however, some schools that have been leading the way when it comes to the move from content-based to competency-driven outcomes for students, with the aptly named PSII serving as a prime example in BC.

This chapter provides an overview of an exploratory case study facilitated at PSII during the 2017-2018 academic year, which focused on a specific facet of their implementation of CBE: assessment. Outlining their unique pedagogy, the impetus for this research, and the development and testing of a novel assessment instrument at the school, the chapter aims to explore the first of the four research questions identified for this project. Specifically:

1. How can the assessment process in a highly-personalized and interdisciplinary K-12 learning environment be adjusted to incorporate competencies more efficiently?

About PSII

Founded in 2013 by the former Superintendent of the Gulf Islands School District, Jeff Hopkins, PSII is an independent secondary school housed in Victoria, BC's downtown core. Built on a new vision for K-12 education in the province, the school provides an interdisciplinary environment where learners in grades 9-12 can pursue their passions through “projects and other learning activities, which take them through a curriculum all their own.” (PSII, n.d.-a). Using an inquiry-based model in which learners define and explore their own research questions outside the context of academic subjects, PSII curriculum is “built on personal curiosity through a close learner-teacher relationship” (PSII, n.d.-a) with educators coaching learners through the inquiry process as they move towards graduation with a BC Dogwood Diploma (see Appendix B).

PSII Assessment and Proposed Graduation Framework

Committed to enabling learners to meet or exceed the BC graduation requirements, an academic checklist consisting of 80 credits of coursework in specific subjects (see Appendix B), PSII's proposed graduation framework goes beyond the subject-specific prerequisites as set out by the BC Ministry of Education (MOE). To this end, it focuses on the development of eight competencies (e.g., Personal Planning and Responsibility) across 11 contexts (e.g., Scientific Process and Application), moving student assessment away from this checklist model towards a more valuable source of feedback. As such, instead of simply representing a box to check, this new graduation framework serves as a living document—a *competency mosaic*—providing an opportunity to both showcase areas of student success, as well as to highlight areas for further development, with each of the contexts representing a new area for growth (see Figure 1).

Figure 1.

Proposed PSII Graduation Framework

The model is based on the concept of “consilience,” (the unity of knowledge), where intersection points between objectives and competencies (rather than behavioural outcomes organized by separate subjects) form the basis of assessment and, thereby, what learning is recognized by schools.

| Proposed PSII Graduation Framework | | Competency | | | | | | | |
|------------------------------------|--|---------------------|---------------------------------------|-----------------------|------------------------------|--------------------------------|--------------------------------------|--------------------------------|--------------------------------------|
| | | Ecological Literacy | Reading, Writing, Speaking, Listening | Mathematical Literacy | Collaboration and Leadership | Critical and Creative Thinking | Cultural Awareness and Understanding | Information and Media Literacy | Personal Planning and Responsibility |
| Objective/ context | Scientific Process and Application | | | | | | | | |
| | Significant Events and Figures in History | | | | | | | | |
| | Artistic, Literary, and Musical Expression, and Appreciation | | | | | | | | |
| | Identifying, Approaching, and Solving Problems | | | | | | | | |
| | Physical and Mental Health, Development, and Lifestyle | | | | | | | | |
| | Indigenous Peoples | | | | | | | | |
| | Structured and Unstructured Play | | | | | | | | |
| | Explore Physical Universe | | | | | | | | |
| | Ethics Awareness and Application | | | | | | | | |
| | Designing and Making Things | | | | | | | | |
| | Language Acquisition | | | | | | | | |

Note. PSII Graduation Framework. Reprinted from “Proposal for a New Prototype Graduation Program” by PSII, n.d., Retrieved December 13, 2021, from <https://slidetodoc.com/proposal-for-a-new-prototype-graduation-program-psii/>. Copyright by PSII. Used with Permission.

While an innovative framework, as an institution subject to the BC Independent Schools Act, the PSII model is ultimately one that exists within the confines of a much more rigid government reporting structure since its foundation in 2013. As such, although inherently competency focused in their pedagogy, major assessment and reporting instruments at the time of this study remained obligated to report extensively on course-based outcomes as prescribed by MOE mandates. This reporting dichotomy is particularly apparent when reviewing the assessment instruments being used by educators in 2016 (see Figure 2). In these documents, while competency assessment is a predominant feature, course-based measures such as percentage of course completion, final course mark and depth of understanding of course content seemingly present far more opportunities for ongoing and detailed feedback.

Figure 2.*PSII Student Progress Report*

| MM YYYY - Progress Report Name: X | | | | | | | |
|---|---|-------------------------|--|----------|---|---|---------------------|
| Competency | | | | Comments | | | |
| Ecological literacy | | | | | | | |
| Reading, writing, speaking, and listening | | | | | | | |
| Mathematical literacy | | | | | | | |
| Collaboration and leadership | | | | | | | |
| Critical and creative thinking | | | | | | | |
| Cultural awareness and understanding | | | | | | | |
| Media and information literacy | | | | | | | |
| Personal planning and responsibility | | | | | | | |
| Course | Approximate % of course completed | Final Course Mark | Average depth at which course outcomes are being addressed | | | | Additional Comments |
| | | | D | E | F | P | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

Note. This figure represents the 2016 version of progress reports, which have since been updated.

K-12 Innovation Partnership

Although existing within these rigid governmental guidelines, as a school founded on the vision of a true competence-based graduation framework for BC students, PSII administration recognized the need to better support learners in their progression towards competence, rather than simply satisfying course-based learning outcomes. And so, in 2015, the educational team at PSII, led by educator Jessica Asp, submitted a proposal to the *K-12 Innovation Partnership* (see Appendix A), an initiative of the BC MOEs 2015 “K-12 Innovation Strategy” (Government of

British Columbia, 2015) intended to support “educators throughout B.C. who are interested in – or already are – pursuing innovative teaching and learning practices that benefit students in the K-12 system” (K-12 Innovation Partnership, n.d.-a). Providing the PSII team with access to additional resources to further research their innovative model, the proposal was officially submitted to gain support for their work in “the building and deployment of an interdisciplinary, competency-based digital portfolio system that ties learning artifacts to competencies and contexts” (K-12 Innovation Partnership, n.d.-b), ultimately serving two additional purposes.

The first of these purposes was to highlight the impact of the schools inquiry model on learner development, helping to showcase the value the inquiry-model can have if applied in other educational contexts. The second was to support their move from the traditional *course-based, criterion-referenced* assessment model to a *competency-based, ipsative* assessment model, helping learners move toward mastery along a competency continuum. Considering the need for both evidence of positive learner experience, and an effective assessment framework, for any administrators looking to implement this type of pedagogy into their school, these two purposes then seemingly represented opposite sides of the same coin, highlighting the important components of the proposal submitted through the *K-12 Innovation Partnership*.

With limited internal resources available to facilitate research on the impact of their inquiry-based model or its implementation, in late 2016 PSII administrator’s contacted faculty members at the University of Victoria (UVic), along with independent researchers in the local community, to seek support in studying the PSII model through both a qualitative and quantitative lens. Considering the multifaceted nature of the proposal, two research teams were ultimately engaged to facilitate the project deliverables, one led by independent researcher Dr.

Heather Hopkins focused on what was described as *qualitative* research, and the other from UVic—including Dr. Ulrike Stege, Dr. Todd Milford and myself—focused on more *quantitative* research. With numerous aspects of the proposal available as prospective research topics, ranging from the reliability of portfolio-based assessment to the validity of CBE, a more practical direction was chosen by the UVic team, aiming not to explore select aspects of the PSII model, but instead to create a research-informed resource which would support processes already in place at the school. Selecting the core competency of *mathematical literacy* as an appropriate starting point for the case study—based on expertise available through members of the UVic team—in the fall term of the 2017-2018 academic year, the quantitative aspect of the PSII research project commenced, seeking to explore how the mathematics assessment process might be adjusted at PSII through a competency-based lens.

Methodology

Taking place over two academic years, the PSII study was multi-faceted, involving not only the development of a theoretical understanding of CBE, but also a practical one. The following section outlines the multi-stage process used to develop this practical understanding in the PSII exploratory case study, beginning with a description of interviews and a literature review which provided perspective on current and best-practices for CBA. The section ends with an overview of both the process by which a novel assessment instrument was developed to support practices at the school, and the study design used to test its implementation.

Teachers Interviews

With a focus on identifying what adjustments might be necessary to better align the mathematics assessment processes at the school with the competency development process,

initial stages of the PSII study entailed interviews with school staff to learn more about their current practices, and specific strategies used to evaluate student development in mathematics. Taking place in late 2016, this process involved relatively unstructured conversations about the PSII model along with a review of existing assessment resources. Interviews with the teaching staff revealed an assessment process driven largely by conversations between students and teachers, along with learner reflection and teacher observation of learning activities. These activities, along with consensus driven educational team meetings—which took place on a semesterly basis—served as evidence for the PSII administration to create reports that could both satisfy the requirements of the BC MOE and their own competency-based graduation structure.

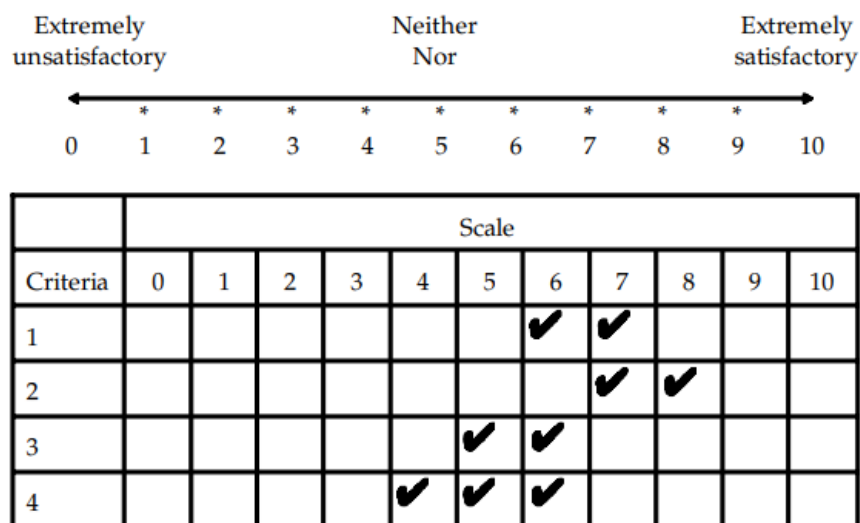
Literature Review

With a basic understanding of current assessment practices being used at the school, the next stage of the research process focused on a preliminary examination of literature regarding mathematical literacy and portfolio assessment. Using Google Scholar as the primary search index, “mathematical”, “literacy”, and “assessment” were chosen as the requisite search terms with no additional restrictions. This search resulted in extensive results, but few in the context of secondary education. The terms “portfolio”, “assessment”, “competence”, and “secondary education” were then added to the search, again using Google Scholar, similarly resulting in an extremely broad selection of literature, most of which concerned applications of CBA in post-secondary education (Abadel & Hattab, 2013; Bok et al., 2013; Gadbury-Amyot et al., 2003; Gadbury-Amyot et al., 2014; Tzeng, 2004). Despite many of these initial results having limited relevance in the K-12 context, a selection was chosen for further review, ultimately serving as the basis for the portfolio-focussed CBA instrument that was used later in this study.

The first of these applicable resources was a proposed competency-based portfolio assessment framework developed by Dr. Chahid Fourali, a Senior Lecturer in Management at the London Metropolitan University Business School. Intended for use in vocational training environments (Fourali, 1994; 1997), the model incorporated the concept of fuzzy logic, or “the logic underlying approximate, rather than exact, modes of reasoning” (Zadeh, 1988, p. 83), to implement an 11-point *fuzzy rating scale* (see Figure 3) that could help evaluate sections of a portfolio (e.g., Account of Experience, Witness Testimony) based on select perspectives, such as authenticity and relevance. While not originally designed for use in a K-12 environment, the interchangeability of perspectives used in the model, and its focus on reliability, presented a unique opportunity to incorporate other relevant competence factors, such as those found in the proposed graduation framework at PSII.

Figure 3.

Fuzzy Rating Scale for Portfolio Assessment

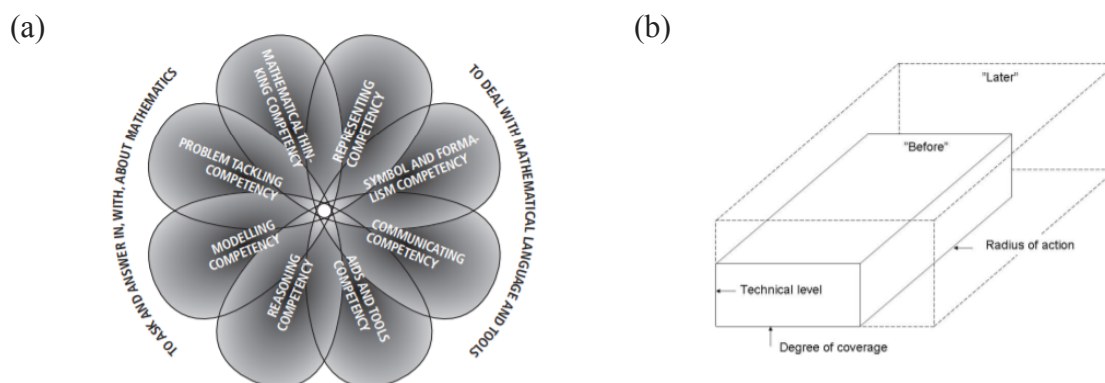


Note. Fuzzy Rating Scale. Reprinted from "Using Fuzzy Logic in Educational Measurement: The Case of Portfolio Assessment" by Chahid Fourali, 1197, *Evaluation & Research in Education*, 11, p. 139. Copyright 1997 by Chahid Fourali. Reprinted with permission.

While the work by Fourali (1994; 1997) was found to include the most detailed description of a portfolio-based CBA instrument, this was not the case for literature examining mathematical literacy in K-12 education. To this end, two specific resources were identified, which presented mathematical literacy in a way that could be easily incorporated into the Fourali (1994; 1997) model. The first of these was a report on “Danish Competencies and the Learning of Mathematics (KOM) Project” (Niss & Jensen, 2002; 2011), an initiative of Denmark’s MOE which sought to build a platform for in-depth reform of Danish math education. The final report, published by Director Mogens Niss in 2002, identified eight converging areas of competence and three interconnected dimensions of mastery, necessary for a student to demonstrate mathematical competence. Similar to the model presented by Fourali (1994; 1997), this paper also included incredibly useful visualizations for the pedagogical layperson, with the illustrations presented by Niss and Jensen (2011) demonstrating intersectionality of mathematical competence areas and the process of progression towards mastery in an extremely accessible manner (see Figure 4).

Figure 4.

Visualizations of Mathematical Competency and Dimensions of Mastery

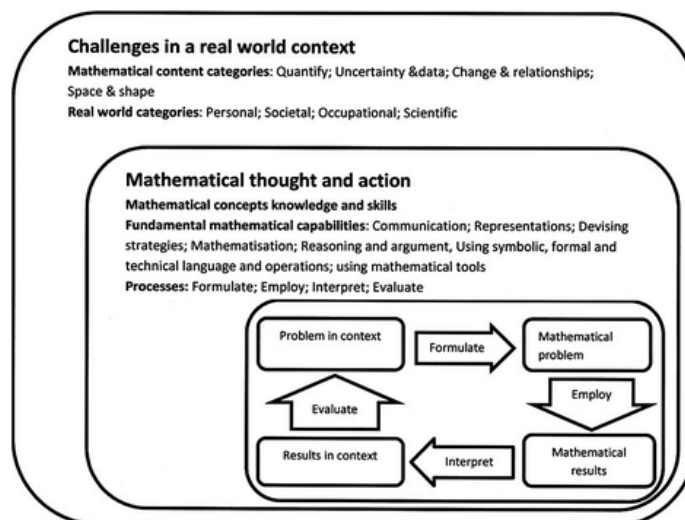


Note. Visualization of (a) mathematical competency and (b) dimensions of mastery. Reprinted from "Competencies and Mathematical Learning: Ideas and inspiration for the development of mathematics teaching and learning in Denmark" by M.A. Niss & T.H. Jensen, 2011, *Roskilde Universitet*, p. 41/141. Copyright 2011 by Mogens Niss. Reprinted with permission.

Niss and Jensen's (2002; 2011) competence areas and dimensions of mastery were later redefined in the final resource, the OECD Programme for International Student Assessments' (PISA) 2015 Assessment and Analytical Framework (OECD, 2016), an internationally recognized assessment program targeted at 15-year old students around the globe. Reconceptualized in the 2015 OECD-PISA framework as the seven *fundamental mathematical capabilities* and three *processes* that constitute literacy in mathematics (see Figure 5), these two variables would become vital aspects of the adapted form of Foureli's (1994; 1997) framework used in the PSII study. Providing a solid theoretical basis for the new CBA instrument, the use of the OECD-PISA framework was a practical choice as well, helping to support the validity of the tool—and hypothetically the likelihood results might be acceptable in mainstream K-12 institutions—due to the widely accepted nature of OECD-PISA results as a measure of STEM literacy around the world.

Figure 5.

Mathematical Literacy as defined by OECD



Note. OECD Mathematical Literacy. Reprinted from "Conceptualisation of the Role of Competencies, Knowing & Knowledge in Mathematics Education Research" by M.A. Niss, N. Planas, R. Turner & J. A. Villa-Ochoa, 2017, *ICME*, p. 242. CC BY 3.0.

Developing a CBA Instrument

Utilizing the findings from the preliminary literature review, the next stage of the research process involved the creation of a novel CBA instrument by the UVic research team. Through this process, the proposed CBA framework introduced by Fourali (1994; 1997) was adapted to use the processes and capabilities as outlined in the 2015 OECD-PISA framework. Created using the Google Suite, and provided to participants as both an editable Google Sheet and a fillable PDF document, the instrument included an area to assess each of the OECD-PISA fundamental mathematical capabilities (further referred to as mathematical competency areas) across each of the three OECD-PISA mathematical processes. As in the Fourali (1994; 1997) *fuzzy rating scale*, 11 cells were provided in each of the competence categories on the form, corresponding to the various competency development stages—along a continuum—moving from beginning to developing, expanding, fluent and finally proficient (see Figure 6).

Figure 6.

Google Sheets Assessment Form: Version 1

| Learning Artifact Competency Assessment | | | | | | | | | | |
|--|-------------|-----------|------------|---------------------|-----------|------------|---------------------------------------|-----------|------------|--|
| Learner Name: | | | | Assessor Name: | | | | | | |
| Date of Artifact Creation: | | | | Date of Assessment: | | | | | | |
| Description of Artifact: | | | | | | | | | | |
| Mathematical Competency Area | Formulating | | | Employing | | | Interpreting, Applying and Evaluating | | | |
| | Beginning | Expanding | Proficient | Beginning | Expanding | Proficient | Beginning | Expanding | Proficient | |
| | Developing | Fluent | | Developing | Fluent | | Developing | Fluent | | |
| Communicating | Assessment | | | | | | | | | |
| | Comments | | | | | | | | | |
| Mathematising | Assessment | | | | | | | | | |
| | Comments | | | | | | | | | |
| Representation | Assessment | | | | | | | | | |
| | Comments | | | | | | | | | |
| Reasoning and argument | Assessment | | | | | | | | | |
| | Comments | | | | | | | | | |
| Devising strategies for solving problems | Assessment | | | | | | | | | |
| | Comments | | | | | | | | | |
| Using symbolic, formal and technical language and operations | Assessment | | | | | | | | | |
| | Comments | | | | | | | | | |
| Using mathematical tools | Assessment | | | | | | | | | |
| | Comments | | | | | | | | | |

Note. Cells in the assessment rows represent the *fuzzy rating scale* which would be populated by adding an (x) in the appropriate squares for each competency area based on selected levels.

This *Learning Artifact Competency Assessment Form*, which fundamentally broke down mathematical literacy into 21 unique areas to be assessed (i.e., three processes for each of the seven competency areas) allowed individuals to select the lowest and highest levels of competence which they understood to be demonstrated through a given learning artifact along the 11-point *fuzzy rating scale*. The instrument also included an opportunity for participants to provide written comments to support their assessments for each of the artifacts examined, ideally helping to increase the reliability and validity of the results. Finally, to support the use of this new assessment instrument by a more general audience, the form was accompanied by a single-page rubric—based on the 2015 PISA Mathematical Literacy Assessment Framework (OECD, 2017, p. 71-72)—providing the relevant indicators expected to be present for learners to demonstrate competence in each of the 21 mathematical competency areas (see Figure 7).

Figure 7.

Mathematical Competency Assessment Rubric

| Mathematical Competency Assessment Rubric | | | |
|--|--|---|---|
| | Formulating situations mathematically | Employing mathematical concepts, facts, procedures and reasoning | Interpreting, applying and evaluating mathematical outcomes |
| Communicating | Read, decode, and make sense of statements, questions, tasks, objects or images, in order to form a mental model of the situation | Articulate a solution, show the work involved in reaching a solution and/or summarise and present intermediate mathematical results | Construct and communicate explanations and arguments in the context of the problem |
| Mathematising | Identify the underlying mathematical variables and structures in the real world problem, and make assumptions so that they can be used | Use an understanding of the context to guide or expedite the mathematical solving process, e.g. working to a context-appropriate level of accuracy | Understand the extent and limits of a mathematical solution that are a consequence of the mathematical model employed |
| Representation | Create a mathematical representation of real-world information | Make sense of, relate and use a variety of representations when interacting with a problem | Interpret mathematical outcomes in a variety of formats in relation to a situation or use, compare or evaluate two or more representations in relation to a situation |
| Reasoning and Argument | Explain, defend or provide a justification for the identified or devised representation of a real-world situation | Explain, defend or provide a justification for the processes and procedures used to determine a mathematical result or solution Connect pieces of information to arrive at a mathematical solution, make generalisations or create a multi-step argument | Reflect on mathematical solutions and create explanations and arguments that support, refute or qualify a mathematical solution to a contextualised problem |
| Devising Strategies for solving problems | Select or devise a plan or strategy to mathematically reframe contextualised problems | Activate effective and sustained control mechanisms across a multi-step procedure leading to a mathematical solution, conclusion or generalisation | Devise and implement a strategy in order to interpret, evaluate and validate a mathematical solution to a contextualised problem |
| Using symbolic, formal and technical language | Use appropriate variables, symbols, diagrams and standard models in order to represent a real-world problem using symbolic/formal language | Understand and utilise formal constructs based on definitions, rules and formal systems as well as employing algorithms | Understand the relationship between the context of the problem and representation of the mathematical solution. Use this understanding to help interpret the solution in context and gauge the feasibility and possible limitations of the solution |
| Using mathematical tools | Use mathematical tools in order to recognise mathematical structures or to portray mathematical relationships | Know about and be able to make appropriate use of various tools that may assist in implementing processes and procedures for determining mathematical solutions | Use mathematical tools to ascertain the reasonableness of a mathematical solution and any limits and constraints on that solution, given the context of the problem |

This single-page rubric would be further extended prior to the commencement of the data collection period in 2018 by participating mathematics educators at PSII, to include three additional pages: one page expanding on each of the OECD-PISA mathematical processes (see Appendix B). This extension was included in the study for two primary reasons. Firstly, it helped to make language more accessible for students involved in the assessment process. Secondly, it supported non-mathematics trained educators at PSII in use of the form who might have limited experience with assessing the relevant secondary mathematics curriculum.

Testing of the Novel CBA Instrument

Participants. Considering the unique nature of assessment at PSII (i.e., the role of both learners and educators in the assessment process) two groups of participants were recruited for the study, with Group 1 representing current educators at PSII and Group 2 representing current learners at the school in grades 9-12. Following Group 1 recruitment activities in 2017, which involved numerous individual and group meetings with the PSII instructional team, six educators submitted their consent to participate. This group included representation from both those trained in, and responsible for, delivery of regular mathematics seminars to PSII learners, and non-mathematics educators at the school interested in supporting the research.

Following the confirmation of Group 1 participants, recruitment of Group 2 participants commenced in early 2018 through both in and after-school presentations supported by PSII administration. These activities led to a total of 27 learners, and where necessary their guardians, consenting to participate. To ensure confidentiality, all assessments were anonymized by the PSII team prior to submission, assigned a unique identifying number (i.e., Learner 1) and having any personally identifiable information redacted as per the ethics application (see Appendix D).

Procedure. Intended to serve as a test of Fourali's (1994; 1997) theoretical assessment framework in a real-world learning environment, participants were provided significant freedom regarding their use of the CBA instrument during the data collection period. This period commenced in February 2018 and concluded in April 2018, with exception of the two-week spring break that took place between March 16th and April 4th. Following initial meetings which introduced the assessment instrument and framework, participants were provided with detailed instructions regarding form completion and submission. These instructions most notably included that the tool was not intended to replace any of the current assessment processes, and as such was not a necessity to complete for every assessment related to mathematical literacy.

With copies of the form available digitally, and a summary of the instructions sent to the educational lead at the school, participants were encouraged to make use of the CBA instrument wherever practical to assess a wide variety of learning artifacts, not only those created in a math context. Additionally, participants were informed that multiple forms could be completed for the same learning artifact by different participants, including students themselves. For any learning artifact assessed, participants were instructed to provide researchers with a copy of associated instructional materials linked to its creation, along with an image or copy of the artifact, and any additional learner reflections or assessment notes made around the assessment.

In the instructions provided to the PSII educational team lead, participants were told to, based on their understanding of the annotated rubrics provided (see Appendix C), identify relevant fundamental capabilities they felt had been demonstrated through the learning artifact, and assess that capability in the appropriate table cells based on the mathematical processes observed. When assigning marks along the *fuzzy rating scale* (i.e., competency continuum) for

each category, participants were instructed to identify the lowest and highest levels of competence demonstrated therein, adding a continuous spread of marks between those points. While not mandatory, participants were also provided with the opportunity to provide comments in addition to, or in place of, the fuzzy rating scale in any given category. Following completion of the assessment form, the document and all supporting information was to be either emailed to the research team or left with PSII administration to be collected in person.

To help study participants understand the workflow of the new CBA process, training was provided prior to the start of the data collection period. This training involved the use of a sample learning artifact created at the school (i.e., a dress design) to demonstrate how the assessment process would work in a real-life scenario. During this training, after having the artifact described in a mock assessment conversation, participants were provided with the potential mathematical competencies (i.e., devising strategies for solving problems) that might align with designing the dress. They were then shown how to use the rubric to determine which fundamental processes might be evident, and finally how to complete the fuzzy rating scale.

Initial Results

After reviewing the submissions provided by PSII administration following the end of the data collection period in April 2018, 23 individual forms were found to be completed. All had utilized the Google Sheets template provided rather than the fillable PDF form. Representing evaluation of 63% of the possible Group 2 participants, these forms were created and completed by four of the six educators, with two of those six members facilitating approximately 70% of the assessments, and the others divided evenly between the remaining two educators. Of the 17 students for whom assessments were completed, only three were assessed more than once over

the study period, with no two assessments completed for the same learning artifact, and only two students assessed by the same educator on multiple occasions. No forms submitted had been completed as either self or peer-assessments by any of the Group 1 participants. Additionally, while details concerning the learning artifacts associated with each submission were provided, additional attachments (i.e., images of the original artifact) were provided in only four cases.

Despite the lack of access to the original learning artifacts for more than 80% of the forms submitted, a review of the *Description of Artifact* and written comments on the CBA instruments found assessments to involve mathematical literacy demonstrated across a wide variety of subject areas. To further investigate this finding, each of the 23 forms were analyzed and correlated to existing courses in the BC secondary curriculum. These results show that while mathematics remained the most common subject area related to the assessments, representing 43% of the total submissions, learning artifacts assessed using the CBA instrument in the study could be linked to nine additional subject areas in the BC secondary curriculum. These subjects included Chemistry, Physics, Psychology, Physical Geography, Engineering, Computer Programming, Media Design, Music and Culinary Arts. A detailed overview of the assessment forms submitted as part of the 2018 PSII study as completed by each educator and broken down by learner and subject area, can be found in Figure 8.

Figure 8.*PSII Study Assessment Submissions by Educator, Learner and Subject Area*

| Learner | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|------------|---|---|---|---|---|---|---|---|---|
| Educator A | 1 | | | 1 | | | | 1 | |
| Educator B | 1 | | | | | | | | |
| Educator C | | 1 | | | 1 | 1 | | | 1 |
| Educator D | | | | | 1 | | 1 | 1 | |
| Educator E | | | | | | | | | |
| Educator F | | | | | | | | | |

| Learner | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|------------|----|----|----|----|----|----|----|----|----|
| Educator A | | | | 1 | | | | | |
| Educator B | | | | | | | | | 1 |
| Educator C | | | 1 | | | | | 1 | |
| Educator D | 1 | | | | 1 | | | | |
| Educator E | | | | | | | | | |
| Educator F | | | | | | | | | |

| Learner | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|------------|----|----|----|----|----|----|----|----|----|
| Educator A | | 1 | | | | | | | |
| Educator B | | | | | | | | | |
| Educator C | | | | | | 1 | 1 | | |
| Educator D | | | | | 1 | 1 | | | |
| Educator E | | | | | | | | | |
| Educator F | | | | | | | | | |

| | | | | |
|---------------|------------|--------------------|---------|----------------------|
| Math | Chemistry | Physical Geography | Physics | Media Design |
| Culinary Arts | Psychology | Engineering | Music | Computer Programming |

Note. Psychology is not a course outlined in the formal BC curriculum documents but it can be found as a Board Authority Authorized (BAA) Course in many school districts across BC.

Much as there was variability in the subject areas related to the submissions, there was also extensive variability concerning the content of the assessment forms themselves. To this end, more than 90% of the submissions were found to show use of a combination of comments and the competency continuum, with examples of both comments and competency continuum alone found as well. Noting a trend towards the use of less comments and a shorter spread of marks along the fuzzy rating scale as the data collection period progressed, analysis also revealed educators to be extremely conservative in their use of the continuum spread as a whole. This was reflected in only 30% of educator submissions demonstrating a spread of more than five marks along the continuum, and an average spread of three. While the use of the fuzzy rating scale within individual categories of competence was seemingly conservative, this was not reflected in how often they were used to assess competence across the 21 available categories. This was seen in 90% of the form submissions assessing a learning artifact across all three of the mathematical processes, and 70% of the forms assessing six or more of the seven mathematical capabilities.

In addition to the form submissions themselves, further anecdotal data was collected following the formal data collection period in April 2018, through verbal and written comments provided by Group 1 participants. This data came through a request for participating educators to provide qualitative feedback on how the form usage had impacted their regular assessment practices. While this feedback was limited to only a handful of participants, it specifically noted that more time was being spent on completing the assessments as opposed to regular assessment practices, including time outside of the school day. This resulted in these forms often taking the place of the type of assessment notes an educator might normally use. This additional time was reportedly due to two main factors. The first of these was the extensive delineation of math

literacy into the 21 categories, complexity which made the process of determining areas of assessment and note-taking much more cumbersome. The second reason was that educators involved in the study were attempting to craft notes that could be easily understood by the research team. This second finding, which highlighted the impact of the “behaviour-modifying effects of being the subject of a social investigation” (Wickström & Bendix, 2000, p.1)—also known as the *Hawthorne Effect*—was particularly troubling, as it elucidated the potential for other mitigating biases which may have not been accounted for in the original study design.

Summary of Chapter 2.

This chapter reviewed the implementation of a modified version of the Fourali (1994; 1997) competency assessment framework at PSII in 2018, seeking to examine the first of four primary research questions involved in this project. Specifically:

1. How can the assessment process in a highly-personalized and interdisciplinary K-12 learning environment be adjusted to incorporate competencies more efficiently?

Building on the observation-centric CBA system already in place at PSII, the Google Sheets based form developed for the study was intended to supplement the extensive note-taking and documentation already used for mathematics assessment at the school. Incorporating the capabilities and processes from 2015 OECD-PISA Assessment Framework, the CBA instrument aimed to provide a way to more accurately assess student progression through a competency continuum in math. With more than 50% of the schools full-time teaching staff and 20% of the student population consenting to participate in the study, 23 assessments were submitted over the course of the nearly two month data collection period. Data from these submissions showcased the interdisciplinary nature of mathematical literacy, and revealed aspects of the assessment

model to have significant potential in the PSII learning environment, particularly when supported with additional time and the necessary resources to fully understand the CBA process. Results, however, also identified significant issues with both the study design and the instrument itself, particularly concerning the complexity of categorizing feedback related to learning artifacts. Ultimately, despite a focus on increasing validity and reliability of math assessment at PSII, the study revealed a lack of evidence that this tool was effective in either case, with the issues surrounding efficiency and clarity limiting the ability for multiple assessments to be completed.

The prevalence of these issues highlighted additional research which was required not only around the use of this instrument in an active interdisciplinary teaching environment, but also around some of the core assumptions underlying its creation and use at PSII, including:

1. What are the established best practices for assessment in competency-based education?
2. Are portfolios effective assessment tools for use in competency-based education?
3. What are appropriate frameworks to use when assessing mathematical competency?

These questions then served as the impetus for the next stage of the research process, which aimed to both improve efficiency of the tool for use across the K-12 educational landscape, as well as to provide a more solid theoretical understanding of some of the core pedagogical components related to its usage (i.e., portfolios and competencies).

Chapter 3: Post-Study Literature Review

Following completion of the data collection period in April 2018, initial results were provided to the wider academic community in the form of a conference presentation at the third Creative Mathematical Science Communication (CMSC) Conference in Wellington, New Zealand (MacLean et al., 2018). Providing an overview of the research project to date, this presentation outlined successes and challenges of the study, as well as recommendations on how to make use of the tool more efficient for teachers in K-12 institutions. With the associated conference paper shared with the PSII administration team following the conference, in August 2018 research was postponed indefinitely due to availability of researchers involved in the project. This included, most notably, the primary researcher (i.e., myself) who returned to undergraduate studies at UVic to pursue a Diploma in Secondary Teacher Education, intended to gain a better understanding of the challenges facing teachers in the modern classroom.

Scope of Literature.

Resuming in January 2020 following my completion of the diploma program, and building on lessons learned from the 2018 PSII study, the next stage of the project focused on a more thorough exploration of scholarly research concerning portfolio-focused CBA in secondary education. Recognizing the lack of relevant literature identified using Google Scholar in the first stages of the project, the search terms were revisited using the UVic Libraries Summon 2.0 search engine, with the selected phrases revised to include “competency assessment”, “mathematics”, “secondary education”, and “portfolios”. Limiting the results to only scholarly and peer-reviewed journal articles published since 2015, a very small selection of literature was again identified, with results continuing to focus on assessment practices in

post-secondary education. Expanding the search to include publications since 2010 increased the articles significantly, but again, a limited number were relevant to the topic.

Based on these results, an appropriate scope of literature was determined to be any scholarly journal articles covering the topic of portfolio-focused CBA across all levels of education. Building on the literature identified during the initial stages of the PSII study, a total of 20 empirical studies were selected for this review, all of which addressed CBA practices in secondary or post-secondary education, with 14 specifically addressing the use of portfolios in the competency assessment process. Additional academic and vocational literature was also included to provide background context for the review, and to support discussions related to the findings in these empirical studies. Research items selected prioritized scholarly, peer-reviewed literature published since 2000, but allowed for the inclusion of additional research deemed relevant to the topic of CBA, resulting in a selection of literature dating from 1973-2019.

Purpose of the Review

The purpose of the literature review was to further explore the use of educational portfolios to assess mathematical competency development in secondary schools, building on the initial stages of the research project regarding the implementation of a portfolio-based assessment system at PSII (MacLean et al., 2018). This was accomplished by examining current practices related to assessment in CBE, examining how educational portfolios are effectively used for assessment in those learning environments, and exploring the concept of mathematical literacy through a competency lens. Having jumped very quickly into the PSII project in 2018, the objective of this review was to take a step back from creating an instrument to support existing processes at the school, and instead explore whether some of those processes were even

appropriate to assess mathematical literacy development in such an environment. To this end, this literature review focussed on three major inquiry questions:

1. What are the established best practices for assessment in competency-based education?
2. Are portfolios effective assessment tools for use in competency-based education?
3. What is the appropriate framework to use when assessing mathematical competency?

Competency Assessment in Education

Even a cursory exploration of an academic database or a popular search engine leaves little doubt of the popularity of CBE in 21st century higher education (Cates et al., 2020; McGuire & Lay, 2019; Tonni et al., 2020), with publications such as the *Journal of Competency-Based Education* dedicated entirely to disseminating such research, and noteworthy journals from the *Journal of Technical Education and Training* to *Medical Teacher* publishing extensively on the topic. When exploring practical applications of CBA, however, particularly outside of post-secondary education environments, the literature is much more limited, with the “steep price in time and personnel resources” (Spady, 1977, p. 11) and the resulting exhaustion for teachers (Sullivan & Downey, 2015) identified as major challenges for its implementation at the secondary level. While this evidence certainly presents a window into the lack of empirical literature on CBA in K-12, there remains a significant problem, as with few research studies available for reference, it is difficult to understand how a CBA framework might be successfully implemented in a secondary learning environment like PSII. As a result, this first section of the review is focussed on an exploration of the best practices for CBA in any educational context, with the objective of gaining a broader understanding of how the CBA practices used in post-secondary education may apply to the implementation of similar practices in K-12.

Criterion-Sampling. When examining literature related to the implementation of CBA, research stretches back more than forty years, arguably beginning with the work of preeminent American Psychologist Dr. David McClelland and his 1973 paper *Testing for competence rather than for intelligence*. In this paper, McClelland (1973) argued that educational “tests should assess competencies involved in clusters of life outcomes” (p. 9) using observation of real-life task performance, rather than performance on written tests, to infer competence. While McClelland did not provide specific detail around the practical implementation of his theory, more than 30 years later, Stanford University Graduate School of Education emeritus professor Dr. Richard J. Shavelson provided the answer, with his criterion-sampling approach outlined in the 2010 article *On an Approach to Testing and Modeling Competence*.

In this article, Shavelson (2010) proposed that measurement of competency should involve an individual's “overt performance on tasks that ... may be conceived as samples of real-life ‘criterion’ situations” (p. 84) in order to be a reflective measure of an individual's competency (Shavelson, 2013). While Shavelson’s (2010) method built on established strategies for the assessment of competence at the time (Watson, 1994), and could be supported by various existing vocational training programs, he also identified resources challenges in creating such practical testing scenarios, a factor which may help explain the lack of empirical literature on its practical use. Instead, another, more natural form of observation—workplace based assessment (WBA)—is found much more commonly across the CBA literature. With numerous studies from modern medical education presenting an alternative application of McClelland's (1973) competence testing theory, this WBA model demonstrates applicability across a much larger cross-section of the educational spectrum (Bok et al., 2013; Fielding et al., 2019).

Workplace Based Assessment. Unlike Shavelson’s criterion-sampling method, which required the selection and creation of representative scenarios for competency assessment, WBA approaches described in the literature are presented as far less onerous (Bok et al., 2013; Fielding et al., 2019). This is particularly true in terms of preparation, with assessors in WBA identifying pre-determined natural opportunities for students to be observed in actual work environments. The methods in WBA also differ in terms of the scale of the assessment, with Shavelson’s (2013) model providing a cross-sectional view of an individual's competence at time of measurement, while WBA approaches provide a more longitudinal view, with multiple assessments collected over a period of time and aggregated to support the assessment of competence.

Though this review focused on only a few examples, WBA models can be found across the medical education literature from nursing to veterinary science. In these models the professional activities to be assessed—and the relevant observable competence milestones—are defined by governing regulatory bodies, and presented in a developmental manner based on the stage of training and area of specialization (Bok et al., 2013; Rich et al., 2019). These regular, low-stakes workplace-based observations are then used not only in a formative way to guide student development, but through their aggregation and review by a “competence committee” (Rich et al., 2019, p. 1089), to summatively determine an individual's possession of selected professional competencies.

While the specific instruments used in WBA approaches were not described in all identified literature, two relevant studies noted that level of competency was assessed using a likert-style scale, supported by written feedback and collected in a digital portfolio (Bok et al., 2013; Rich et al., 2019). Further investigation into these scales, described in the Royal College of

Physicians and Surgeons of Canada's *Competency By Design* framework as an "entrustability scale" (2017, p. 2), revealed levels of competence based primarily on the amount of supervision required, highlighting the focus in these medical contexts on competency development that moves an individual towards professional, unsupervised practice (McMurray et al., 2017).

Self-Reflection. While observation appeared as the cornerstone of the competency assessment processes in medical education, an element of self-reflection was also present in these contexts as well. Indeed, at least one example in the literature clearly describes that students should use assessment results to help them in the development of their own personal learning or development plans (Rich et al., 2019). Though not directly impacting the summative assessment of competence in medical models such as *Competency by Design* (RCPSC, 2017), elsewhere in the educational literature, reflective practices are much more prevalent in the CBA process. Examples of this include self-assessment as presented in a Taiwanese study on nursing education as a potential solution to reliability and validity concerns (Tzeng, 2004), along with organizations like the American Psychological Association (APA) stating that "self-reflection and self-assessment are key components of the assessment of competence" (Kaslow et al., 2007, p. 445). That said, while some educational literature suggests that the assessment of competency by means of self-assessment "is widely adopted and acknowledged among education personnel worldwide" (Kopaiboon et al., 2014, p. 1804); multiple studies have also demonstrated a tendency of students to significantly over or underestimate their own level of competency (Lind et al., 2002; Abadel & Hattab, 2013). This inaccuracy of estimation in turn has resulted in the general recommendation from educational scholars that self-assessment activities are much more useful for formative assessment, rather than to be used in the determination of competency

(Leutner et al., 2008). Nonetheless, reflection continues to be an important component of many competency assessment practices across the literature, particularly alongside evidence submitted by individuals to regulatory bodies as a part of their professional development process, and in the assessment of prior learning in higher education (Byrne et al., 2009).

Prior Achievement. While direct observation of students during the learning process, either naturally or through simulation, appears as the preferred method for CBA across much of the medical and other vocational literature, the same can not be said for all of higher education. Here assessment of prior learning appears much more regularly in discussions on CBE (Camacho & Legare, 2016; Tate & Keir-Collins, 2013) and in the suggested best practices for CBE over nearly 30 years (McClarty, & Gaertner, 2015; Watson, 1994). In fact, the concept of PLAR in post-secondary education dates back to at least to the late 1940s in the United States, as a method used by the government to provide access to higher education for veterans of World War II (Camacho & Legare, 2016). Evolving extensively since early those post-war days, prior learning assessment in the 21st century is much more widely accessible across post-secondary education, with numerous methods—ranging from oral presentations to challenge examinations—used by students to demonstrate their possession of required knowledge and skills to receive credit from a CBE practicing institution (Joosten-Ten Brinke et al., 2008).

That said, while numerous PLAR assessment methods are detailed across the educational literature, empirical studies have primarily focused on only the most popular of the assessment tools used in the evaluation of prior learning across higher education: individualized portfolio reviews (Joosten-Ten Brinke et al., 2008; Tate & Keir-Collins, 2013). Differing from the portfolios described in many of the medical WBA studies, which were primarily tools to store

the results of observational assessments of work-related tasks, portfolios elsewhere in the CBA literature are defined much more broadly, as “a composition of work that a learner has selected and collected to show knowledge, skills or competencies” including “the reflections of the learner on the selected and collected work” (Joosten-Ten Brinke et al., 2008, p. 57). Even appearing in a small selection of the medical and vocational literature (Byrne et al., 2009; Fourali, 1997), these more open-ended portfolios appear to reflect a larger selection of the best practices identified for CBA, providing support for their use in a K-12 environment like PSII.

Summary. With a history dating back more than 40 years, CBA has evolved considerably for use in 21st century education, building on the primarily observational methods introduced by McClelland (1973), to incorporate evidence including student reflection and artifacts of prior learning in the determination of competence. Highlighting the multi-faceted nature of the competency development process, and the role portfolios play in CBE, these CBA best practices demonstrate two important findings related to our research. Firstly, they demonstrate the appropriateness of the methodology that is used at PSII, and that was investigated in the 2018 study. Secondly, they demonstrate the need for change in assessment practices in K-12 contexts looking to adopt a CBE model. With this general utility of CBE and portfolios supported, the next question to be addressed in the review concerned the effectiveness of portfolios for assessment in these CBE learning environments.

Effectiveness of Portfolios in Assessment

While research on CBA predates that of educational portfolios by nearly a decade, the two topics have followed a similar path of growth in the academic literature, with the use of portfolios in higher education dating back at least 30 years to the now defunct journal *New*

Directions for Experiential Learning (Serling, 1980). Since those early references, portfolios have become a growing topic of research, with practical guides published on a nearly annual basis, and journal articles continuing to connect the use of portfolios to both PLAR and CBA.

Considering this apparent connection between portfolios and CBE, and the proposal by PSII to use digital portfolios in their CBA model, exploring their effectiveness in the assessment of competency seemed an appropriate second question to consider in the literature review.

Reliability, validity and practicality were chosen as quality assessment measures to examine as part of this process, based on both the regular reference to these three concepts in empirical studies, and on assessment best-practices as presented in the scholarly literature (Ormrod, 2003).

Reliability. The APA defines reliability as “the trustworthiness or consistency of a measure,” or “the degree to which a test or other measurement instrument is free of random error, yielding the same results across multiple applications to the same sample” (American Psychological Association, n.d.-b). As evident from this description, the nature of reliability in educational assessment is multi-faceted. That said, despite the importance of both internal and external reliability to the development and use of an assessment instrument, much of the empirical literature found in this review was dedicated to examining the external factors, in particular inter-rater reliability, or “the extent to which independent evaluators produce similar ratings in judging the same abilities or characteristics in the same target person or object” (American Psychological Association, n.d.-a).

A representative example of this focus on inter-rater reliability can be found in a recent study which examined the portfolio assessment system being implemented in two dental schools in the United States of America (Gadbury-Amyot et al., 2014). Similar to many of the CBA

systems outlined earlier in this paper, the portfolios examined in this study allowed for the use of a variety of learning artifacts including observations, patient notes, exams and reflections. However, unlike the models presented elsewhere in which learning artifacts are evaluated individually and then aggregated (Bok et al., 2013; Rich et al., 2019), in this study assessors examined the portfolio in its entirety, determining competency through a collaborative assessment process. Findings from the study revealed that while results had low reliability with a single assessor, inter-rater reliability increased significantly with the presence of a second assessor, allowing for the use of fewer individual criteria in the measurement of competency. A later study (Castanelli et al., 2018) further supported this positive impact of multiple assessors, using another portfolio assessment model involving aggregation of formative assessments. This study found that when assessments facilitated by multiple trained assessors were prioritized, only 15 learning artifact assessments were needed to meet the minimum required reliability for high-stakes summative assessment of competency, with just 9 needed for effective use in lower-stakes formative assessments.

Validity. Similar to reliability, validity is a complex measure in educational assessment, defined as “the degree to which empirical evidence and theoretical rationales support the adequacy and appropriateness of conclusions drawn from some form of assessment” (American Psychological Association, n.d.-c). More succinctly this means validity concerns whether an instrument actually measures what it is intended to measure. This measurement encompasses numerous aspects, from whether a test accurately measures the concept that it is intended to measure (i.e., construct validity) to whether the results of a given test correlated to a different test of the same thing (i.e., criterion validity). Much as with reliability, most of the empirical studies

found in this review explored very few aspects of validity, with the validity of educational portfolio assessment being limited in scope, and even fewer in the context of CBE. Despite these limitations, however, empirical research identified on CBA using portfolios tended to support at least the measure of criterion validity (Gadbury-Amyot et al., 2003), with a smaller 2012 study on the use of web-based portfolio's at a Chinese high school (Chang & Wu, 2013), finding that portfolio scores to be highly correlated with standardized achievement test scores. This is a finding which certainly helps to support the validity of these tools for CBA in general, and their use in the educational assessment context at PSII.

Practicality. While much of the discussion about the value of assessment seems focussed on reliability and validity, even the most valid and reliable tool, if impractical for use in the classroom, can be ineffective. This idea is reflected across much of the literature related to the development of classroom assessments, with educational scholars recognizing that “time is a limited commodity for teachers, and the pace of classrooms is hectic. Assessments should not detract from energy that is needed for instruction and other professional activities” (McMillan, 1999, p. 9). Brown and Abeywickrama (2010) even went so far as to define practicality in assessments as needing to satisfy five discrete criteria, namely to: stay within budgetary limits, be completed by the test-taker within appropriate time constraints, have clear directions for administration, appropriately utilize available human resources, not exceed available material resources, and consider the time and effort involved for both design and scoring (p. 33).

With this in mind, and considering the positive view of portfolio assessment as it relates to validity and reliability demonstrated in the empirical literature (Chang & Wu, 2013; Gadbury-Amyot et al., 2003), practicality presents as a likely factor influencing the lack of use of

portfolio assessment in the K-12 classroom. Kalaw (2016) investigated this hypothesis in the context of secondary mathematics specifically, exploring factors influencing the use of portfolio assessment in mathematics by high school and college instructors in the Philippines. Her results showed that the considerable time needed for assessment was the leading factor limiting educators from using portfolio assessment in their classroom, with the additional time needed for planning instructional activities and to develop grading rubrics identified as compounding factors. While Kalaw's (2016) study was limited in scope, surveying only 35 Filipino educators, her results supported other relevant studies found in North American literature (Wolfe & Miller, 1997), with a recent study of more than a thousand Canadian K-12 educators also finding that just 19% of teachers used portfolio assessment in their practice (Suurtamm et al., 2010).

Summary. With empirical evidence across educational contexts supporting the validity of portfolios, but the necessity for multiple assessors to increase reliability, their use as it relates to the 2018 PSII study appears to be supported by the literature. This is despite issues concerning time constraints, which were echoed in the 2018 study results. With this question addressed, the final stage of this literature review concerned an exploration of the most appropriate framework to use when assessing mathematical competency in such a learning environment.

Defining a Competency Framework

Defined broadly by PSII in their graduation framework as “a working knowledge of the language of math, including what numbers and other symbols mean, how space (both real and imaginary) can be explored and described through math, and choosing mathematical strategies to solve problems effectively” (PSII, n.d.-b), the definition of mathematical literacy differs

significantly across the academic literature. In fact, the terms literacy and competency are often used interchangeably in discussions of CBA in mathematics.

Considering this lack of clarity, and the need for more detailed criteria to effectively implement the types of portfolio-based assessment practices identified in the literature, the final question in this review set out to determine which mathematical competency framework was the most appropriate for use in CBA. This was in turn, to explore whether it had been correct to choose the OECD-PISA framework for the 2018 PSII study. To this end, three frameworks were identified in the empirical literature examined during this review, with the Danish KOM Project (KOM), the Mathematical Competencies Research Framework (MCRF) and OECD-PISA Mathematical Literacy Assessment Framework explored in the following section.

Danish KOM Project. Despite being a framework with minimal support from published empirical research, the Danish KOM study (Niss & Jensen, 2002; 2011) is one of the most widely cited when examining the applications of CBA in mathematics. Undertaken under the direction of a committee of the Dutch MOE in 2000, the purpose of the study was to explore current practices in mathematics learning and assessment in Denmark, and determine what, if anything, could be done to make improvements to the system. Directed by former Secretary General of the International Commission on Mathematics Instruction, and member of the OECD-PISA mathematics expert group, Dr. Mogen Niss, the study defined eight competencies and corresponding objectives required to demonstrate mathematical competence. These competencies included: thinking mathematically; posing and solving mathematical problems; modelling mathematically; reasoning mathematically; representing mathematical entities;

handling mathematical symbols and formalisms; communicating in, with, and about mathematics; and making use of aids and tools (Niss & Jensen, 2002; 2011).

Beyond defining the competencies themselves, the authors went even further in their discussion around competency development, describing necessary facets to consider for assessment, noting degree of coverage, radius of action, and technical level as the three dimensions through which progression towards mastery could be measured (Niss & Jensen, 2002; 2011). Despite its apparent popularity, however, with the study cited in more than 700 academic articles, and the results translated to English nearly a decade after the initial publication (Niss & Jensen, 2011), almost no empirical evidence could be found supporting or negating the value of the framework. Indeed, even the authors themselves cited challenges to the implementation of assessment using this type of multi-dimensional model (Niss & Jensen, 2011). This is particularly evident, as stated by the KOM Project report (Niss & Jensen, 2011) co-author Dr. Tomas Højgaard Jensen (2007) through issues stemming from a historical focus on technical level in mathematics education, and an apparent desire by practitioners to use simple assessment tools rather than the complex instruments required for this innovative framework.

Mathematical Competencies Research Framework. While certainly not as widely cited as the Danish KOM study, the Mathematical Competencies Research Framework (MCRF), was a second framework identified in the empirical literature as potentially holding value in the development of a competency assessment instrument at PSII. Introduced in a conference paper at the mathematics education research seminar in Stockholm, Sweden (Lithner et al., 2010), the MCRF described mathematical competency as encompassing problem solving, reasoning, procedural, representation, connection, and communication competencies. The model also

sought to incorporate some aspect of multi-dimensionality, with the facets of *Interpret*, *Do and Use*, and *Judge* identified as the three competency-related activities (CRAs) which must be exhibited by a student to demonstrate mathematical competence.

While many of the studies exploring the use of the MCRF have yet to be translated to English (Bergqvist et al., 2010), the model has been referenced by various recent empirical studies (Mellroth, 2015), including one in particular from the *Scandinavian Journal of Educational Research* (Boesen et al., 2018). In this study, which provides support for its validity, authors highlighted that competencies in the MCRF could be found in a significant portion of test items on the Swedish national tests in mathematics, despite those tools providing little evidence of assessment of *reasoning* and *reflection*, key components of the CRAs.

OECD-PISA Framework. While identification of empirical research was limited concerning the implementation of the Danish KOM project and the MCRF, this review found that the concepts presented in both were key facets of one of the most highly referenced mathematical competency assessment frameworks in use today, the OECD-PISA Mathematical Literacy Framework. Identified as *mathematical skills* in the original 2000 OECD-PISA framework (Niss, 2015), the 2015 version used for the PSII study continued to make use of the KOM findings, with the Assessment and Analytical Framework document stating specifically that “the PISA 2015 framework uses a modified formulation of this set of capabilities” (OECD, 2017) a term which they use interchangeably with competency as defined by Niss and his colleagues (Niss & Jensen, 2011). Condensing the original eight competencies defined by Niss and Jensen (2011) into seven *fundamental mathematical capabilities*, the 2015 OECD-PISA model also incorporated the three-dimensional nature of the KOM framework into their

determination of literacy, with (i) *formulating situations mathematically*, (ii) *employing mathematical concepts, facts, procedures and reasoning*, and (iii) *interpreting, applying and evaluating mathematical outcomes*, described as the processes through which each of the fundamental capabilities must be exhibited to demonstrate mathematical literacy (OECD, 2017). Considering how closely the development of the PISA framework is linked with the findings of the KOM study, it was surprising to discover a 2019 article from the *International Journal of Science and Mathematics Education* which found that the OECD-PISA test did not significantly measure all of the competencies defined in the KOM framework (Pettersen & Braeken, 2017). Specifically, results from this study showed that “the demands for Representation, and to some extent Mathematizing, appear[ed] almost absent in the teachers’ ratings” of the 84 assessment items examined from the 2012 PISA administered in Norway (p. 419).

Summary. While a review of scholarly literature concerning both the KOM study and MCRF identified evidence to support their use in mathematical literacy assessment, the lack of empirical research or usage outside of Europe leaves questions around their applicability in the North American context of PSII. These concerns, combined with the OECD-PISA framework having been administered seven times over the last 20 years in more than 80 countries, with more than 500,000 students completing it in 2015 alone (OECD, 2016), seems to provide the strongest support for its appropriateness as framework to use when assessing mathematical literacy, further supporting its selection for the CBA instrument used in the 2018 PSII study.

Summary of Chapter 3.

This chapter reviewed scholarly literature regarding the use of portfolios for CBA in secondary and post-secondary education environments, seeking to gain perspective on findings

from the 2018 PSII case study. This perspective was gained through the exploration of three interrelated research questions on assessment in CBE environments. Specifically:

1. What are the established best practices for assessment in competency-based education?
2. Are portfolios effective assessment tools for use in competency-based education?
3. What is the appropriate framework to use when assessing mathematical competency?

Based on evidence presented in the 20 empirical studies reviewed, we found that while there is support for the use of portfolio-based assessment in CBE environments, significant issues exist concerning assessment-related workload associated with the use of portfolios in mathematics education. Therefore, it is necessary to take appropriate measures to decrease this workload, by adapting best practices from educational environments in which portfolios have been successfully implemented in CBE at scale. In particular, this includes the use of strategies such as the aggregation of multiple, low-stakes formative assessments for use in summative assessment, to ease workload challenges associated with the competency assessment process.

Empirical evidence also supported the use of the OECD-PISA Mathematical Literacy framework in the development of the mathematical competency assessment instrument used at PSII, presenting it as the most established of three frameworks examined, and one which incorporates the beneficial aspects of each. While the literature did not directly support the use of portfolios in the CBA processes in secondary math education, considering the lack of available research, evidence of validity limitations of standardized tests, and the extensive use of portfolio assessment in CBE, there is evidentiary support for its use in such an environment like PSII.

Chapter 4: Iterative Development and Implementation

With the literature review providing support for the use of CBA and portfolios in the mathematics-related assessment processes at PSII, by far one of the most significant challenges remaining was the practicality of implementing such an assessment model at scale. Noting that aggregation of lower-stakes formative assessments was a key factor to improving this type of feasibility elsewhere, the weight of this remaining challenge was further emphasized by the fact that no tools had been developed as part of this inquiry process to collate results or evaluate the stage of competency development in this way. With this focus on practicality at the forefront, and using classroom experience and evidence from the empirical literature as a guide, the final stage of research into CBA at PSII involved data-driven iteration on the original form design. This iteration process aimed to make the tool more accessible to learners, and more valuable as a resource for educators to guide learner progression through the competency continuum.

Taking part in multiple stages over the course of more than three years, this development process is outlined in the following chapter, showcasing the features and rationale behind each of the three main revisions to the original assessment tool: (i) Google Sheets Version 2 (ii) Mobile Application Concept, and (iii) Google Sheets Version 3. Moving from the relatively simple modifications to the form made immediately following the data collection period in 2018, to the most recent version developed in 2021, each new revision is iterative, responding to challenges identified in earlier versions. These changes also take advantage of knowledge gained through practical classroom experience, additional research, and independent updates to the competency assessment framework at PSII since 2018.

Version 2 of the Google Sheets Assessment Form

Created immediately following the PSII study in 2018, the first revision to the Google Sheets based assessment form responded primarily to anecdotal comments from participating educators. These comments had identified difficulty in both delineating feedback into so many areas, as well as limiting feedback comments to such discrete categories. Noting the intersectionality of the many different mathematical competency areas, as so eloquently illustrated by Niss and Jensen (2011), the resulting iteration saw the removal of individual comment areas for each of the 21 original categories of competence, combining these into eight extended boxes corresponding only to the mathematical competency areas (see Figure 9).

Figure 9.

Google Sheets Assessment Form: Version 2

| Learning Artifact Competency Assessment | | | | | | | | | | | | |
|--|---------------------|-----------|--------|------------|-----------|---------------------|--------|------------|---------------------------------------|-----------|--------|------------|
| Learner Name: | | | | | | Assessor Name: | | | | | | |
| Date of Artifact Creation: | | | | | | Date of Assessment: | | | | | | |
| Description of Artifact: | | | | | | | | | | | | |
| Mathematical Competency Area | Formulating | | | | Employing | | | | Interpreting, Applying and Evaluating | | | |
| | Beginning | Expanding | Fluent | Proficient | Beginning | Expanding | Fluent | Proficient | Beginning | Expanding | Fluent | Proficient |
| Communicating | Assessment Comments | | | | | | | | | | | |
| Mathematising | Assessment Comments | | | | | | | | | | | |
| Representation | Assessment Comments | | | | | | | | | | | |
| Reasoning and argument | Assessment Comments | | | | | | | | | | | |
| Devising strategies for solving problems | Assessment Comments | | | | | | | | | | | |
| Using symbolic, formal and technical language and operations | Assessment Comments | | | | | | | | | | | |
| Using mathematical tools | Assessment Comments | | | | | | | | | | | |
| Mathematical Competency Area | Beginning | Expanding | Fluent | Proficient | Beginning | Expanding | Fluent | Proficient | Beginning | Expanding | Fluent | Proficient |
| | Formulating | | | | Employing | | | | Interpreting, Applying and Evaluating | | | |

Note. Cells in the assessment rows represent the fuzzy rating scale which would be populated by adding an (x) in the appropriate squares for each competency area based on selected levels.

These initial changes to the form, while seemingly surface level, helped address what would later be attributed to the concept of *choice overload* or “a scenario in which the complexity of the decision problem faced by an individual exceeds the individual's cognitive resources” (Chernev et al., 2015, p. 335). Reducing the number of assessment variables per form from nearly 50 to approximately 30, Version 2 of the Google Sheets assessment form greatly reduced the factors an assessor needed to consider in completing a form, while also helping provide clarity to where the focus of assessment should be, on meaningful (rather than granular) feedback. Also contributing to a reduction in complexity, while not visible on the revised form itself, were additional restrictions on the number of marks which could be assigned along each of the fuzzy rating scales. Originally possible—at least in theory—for an assessor to distribute marks across all 11 boxes, making the *fuzzy standard deviation* (Fourali, 1997) an extremely important additional measure, this revision limited the maximum spread in any continuum to just three boxes, leaning on the findings from the PSII study which saw an average of three used.

Ultimately a practical decision, this additional change reduced complexity and the potential for unintentional human error, while also allowing for more efficient aggregation of marks in a way that stayed true to the fuzzy nature of the model. It also resulted in a reduction in the variability of mark spreads in a single continuum from more than 40 to only 9 discrete variations. This reduction was especially valuable from a reporting perspective, as it enabled the direct translation of the results in each continuum to a more traditional nine-point *stanine* grading scale. This was particularly noteworthy as it would allow for individual areas to be converted to a letter or percentage score without the need for aggregation. While such a use of the form would operate against best-practices from the literature, considering that no work had been done to

build the necessary systems to process the form data at scale, this change would allow for each area to also be a valuable stand-alone evaluation instrument, similar to a traditional rubric.

Mobile Application Concept

While Version 2 of the Google Sheets based assessment instrument certainly reduced complexity, with 30 individual areas remaining to be completed on each form, the overchoice issue was yet to be fully addressed. Changes in this second version had also failed to address the manual amalgamation issues, and challenges from the 2018 PSII study involving the connection of learning artifacts to specific competencies. With addressing these remaining challenges vital to creating a more effective tool, but the UVic team lacking the experience to address them through the Google Sheets format, it was evident that further ideation was required. The result of this ideation, in late 2018, was less a practical and more aspirational revision to both previous versions of the form, a mobile application concept which envisioned how the tool might work given more purpose-built functionality than was available through the Google Suite.

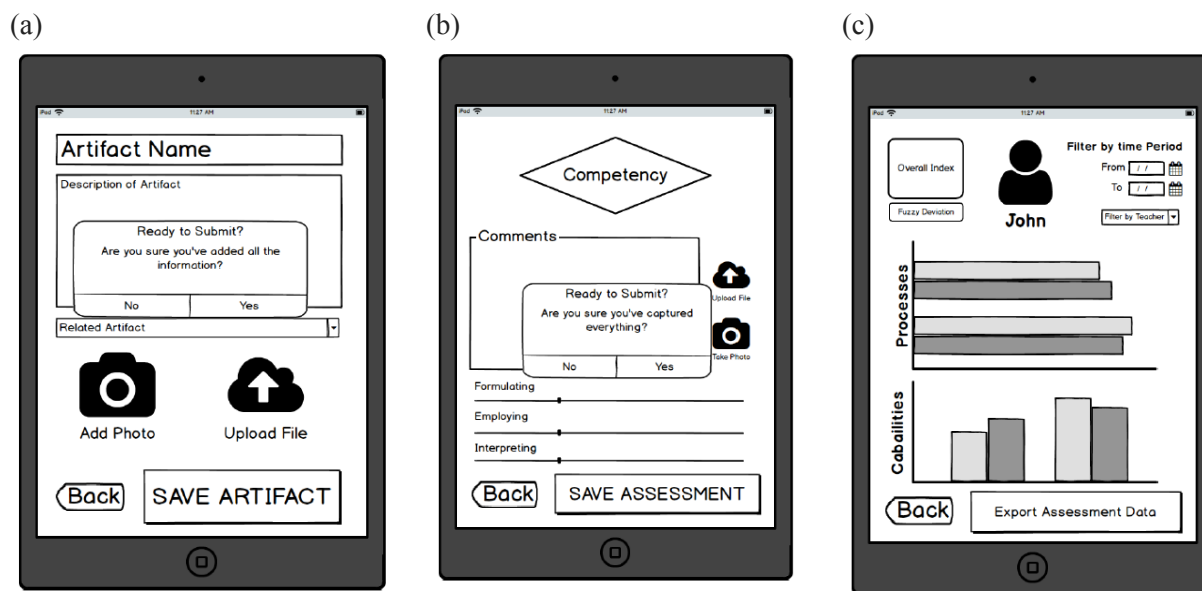
Intended primarily for use on a mobile device (i.e, cell phone or tablet), the application concept—nicknamed *Continuum*—borrowed design inspiration from existing portfolio-based educational assessment applications available on the market at the time, including Fresh Grade, Seesaw, and Mahara. As with many of those platforms, at the centre of this design was the concept of the *artifact upload*, a critical step in the assessment process which required the capturing and tagging of the learning artifact prior to the completion of the assessment itself. Contributing to the ease of use by providing educators with a familiar interface, this workflow also helped to address the lack of access to original learning artefacts which was an issue in the 2018 study. Other challenges which had been observed through the PSII study were also

addressed in this concept, with the inclusion of Computer Vision and Natural Language Processing helping to reduce choice overwhelm by providing data-informed recommendations concerning which competencies might be represented by an uploaded learning artifact.

As part of this ideation process, a basic User Interface (UI) and corresponding User Experience (UX) model was developed, showcasing the simplified interface for completing an assessment (see Figure 10). The aim of this model was two-fold. Firstly, it attempted to demonstrate how the revised tool might be more accessible to individuals who had been intimidated by the relative complexity of the previous form. Secondly, it endeavoured to visualize stages of the assessment process which had only been theorized in the previous version.

Figure 10.

UX/UI Mockup of the Continuum Mobile Application



Note. User experience mock-ups for three screens and stages in the competency assessment process using the *Continuum* mobile application beginning with the (a) upload of an image or copy of the learning artifact, moving onto the (b) input of the competency assessment including comments and fuzzy rating scale selection, and finally a (c) preview of the assessment results.

In the new model, after uploading a photo and description of the learning artifact (see Figure 10a), assessors would be prompted to select an appropriate mathematical competency area they wished to assess. Users would then be presented with a comment area to provide written feedback, and sliders taking the place of checkboxes to define where a learner existed along the competency continuum (see Figure 10b). To address challenges related to interpretation of amalgamated results, this design also included a data visualization feature (see Figure 10c). Supported by submission data being entered directly into a formal database structure, providing more scalable storage of results, this feature capitalized on available visualization libraries to produce relevant charts filtered by learner, educator, and competency. This feature was theorized to be particularly helpful for educators in more clearly identifying areas of success and necessary support for a continued development in a given competency area.

Gaining New Perspectives for Final Form Iteration

Inspired by the relative simplicity of the mobile application concept, but recognizing a lack of available expertise to build such a complex instrument, active development of the tool paused between 2018 and 2020. In the intervening years, three other activities would occur that would inform the final iteration of the assessment instrument: (i) undergraduate coursework related to assessment (as part of the UVic teacher education program), (ii) practical experience as a teacher facilitating and observing assessments, and (iii) additional research related to CBE and portfolios. While these activities varied greatly, they collectively served two critical roles in the final stage of the research process. Firstly, they further illustrated the importance of this project to the field of education as a whole. Secondly, they raised important additional questions

regarding CBE and portfolios which had not been fully considered when the PSII study was originally undertaken. Specifically, these questions were:

1. Have competency-based K-12 reforms meaningfully changed pedagogical practices?
2. Can portfolio assessment be effectively implemented in K-12 mathematics education?

Supplementing, rather than supplanting, the primary research questions, a brief exploration of initial findings related to these sub-questions is provided in the following section, with the impact of those findings applied in the final iteration of the tool in 2021.

Lack of Pedagogical Change in CBE Jurisdictions.

With first-hand experience in secondary STEM classrooms demonstrating the continued use of worksheets and multiple-choice tests by educators in BCs new competency-based curriculum, I was curious to understand whether this lack of change was similar in other areas of the world which had undergone CBE focussed reforms. A review of the literature revealed strong evidence to support my own classroom observations. For example, in a 2014 study of secondary teachers in Tanzania, where this new type of curriculum had been introduced nearly a decade before, authors found that 86% of teachers did not understand the concept or requirements of CBE, and therefore did not adapt their teaching practices (Komba & Mwandaji, 2015). In a similar study in Kuwait, a jurisdiction where the implementation of CBE had been a reported failure following its 2015 introduction, authors found that while teachers saw CBE as an effective tool to enrich the overall educational system, they also recognized insufficient training, lack of awareness in the community, and the general refusal for change, as challenges impacting its successful administration (Sadeq et al., 2020). Even a seemingly more favourable study in England found a clash between the theoretical and practical understanding of teachers when it

came to the application of CBE principles (Byrne et. al., 2013b). With a “clear mismatch between the stated aims of the lesson and what teachers did in class” (p. 357), the study found that subject knowledge remained the predominant focus of CBE classroom lessons, despite skills and competencies communicated both in writing and “explicitly articulated by the teacher” (p. 357). In a related paper exploring planning of curriculum in those same study schools in England, the authors identified assessment of competencies as “a crucial aspect of the overall curriculum implementation and development” process (Byrne et al., 2013a, p. 338), but noted issues with creating “authentic learning experiences” (p. 339) as major challenges to successfully applying CBE in those schools. When combined with the tendency of educators to “revert to the strong vertical discourse of academic disciplines” in their role as “didactic experts” (p. 362), these findings were indicative of the general lack of pedagogical change both reported and observed in jurisdictions purporting to be effectively implementing CBE.

Lack of Understanding of Portfolio-based Assessment.

While initial stages of this project focussed on an exploration of educational portfolios for CBA, new personal experience and research highlighted the necessity to examine how portfolios were being used for assessment in mathematics specifically. Similar to the new investigation into CBE reforms, a review of the literature was elucidating, supporting both personal observations as a teacher, and findings from the original literature review concerning the lack of portfolios in STEM classrooms. For example, in a study investigating the application of portfolio assessment by math teachers in East Java, Indonesia (Lestariani et al., 2018), authors found that despite participants self-reporting on their understanding of authentic assessment, teachers had “difficulty in selecting material that can be used as portfolio assessment” (p. 6).

This, the authors reported, was a result of a lack of practical understanding as to how portfolios are used, and resulted in teachers failing to include artefacts “besides of written test/quiz” in the process (p. 6). These clarity challenges were similarly reflected in an American study on the 1992 implementation of educational portfolios as part of a state-wide assessment program in Vermont (Klein et al., 1995). Here the authors found that overall reliability and consistency of portfolios for assessment in mathematics could be “characterized as disappointing” (p. 248), stemming “from Vermont's decision to allow students and teachers to include virtually any type of piece in a portfolio, insufficient reader calibration, and scoring guides that were too difficult to apply and/or left too much room for reader discretion and interpretation” (p. 254-255).

The only seemingly favorable study—which again came from Indonesia—explored the implementation of a novel electronic portfolio model in a secondary K-12 mathematics context, aiming to determine the validity, reliability and affectivity of a novel tool which the authors of the paper had created (Abidin & Walida, 2014). Similar to the PSII study, this research involved extensive data collection through various methods including documentation, questionnaires and observations of the e-portfolio’s use in grade 10-12 classrooms. Unlike the PSII study, however, the authors in this case found strong support from participating students, teachers and subject matter experts involved in the study, concluding that their e-portfolio “is valid (94,00%), practical (92,78%), and effective (92,37%)”, thereby representing a useful tool in the teaching and learning process (Abidin & Walida, 2014, p. 600). Unfortunately, the article lacked significant detail around data collection and analysis, making it nearly impossible to replicate, and represented such a small sample size (i.e., one class of 15 students) that it is difficult to consider these results in any way representative.

While this research on portfolio assessment in mathematics dated back more than 30 years, a critical review revealed little agreement on the utility of educational portfolios as a tool for assessment in K-12 mathematics education. Indeed, even institutions in similar geographic jurisdictions failed to demonstrate consistency in their findings. Notwithstanding concerns regarding the validity and reliability of the studies themselves, what continued to be clear through this additional research was a lack of universal understanding as to what constitutes portfolio assessment in mathematics—both in general and in CBE contexts—and the requirement to address outstanding issues regarding the validity and reliability of such assessments in K-12 environments.

Version 3 of the Google Sheets Assessment Form

Recognizing the importance of responding to the challenges identified in the literature and through personal experience, an unexpected opportunity to continue development of the competency assessment tool presented in 2021. This came in the form of a part-time position on the educational team at the newly opened Vancouver Island School of Innovation and Inquiry (VISII). As an inquiry-based middle school founded on the same core principles as PSII, VISII similarly required a resource to support their CBA process, and as such was uniquely placed to support further iteration on the novel assessment instrument created for the 2018 study. This opportunity was made even more compelling as it became the first real test of whether this type of a tool would pass the scrutiny of the BC MOE, with the revision to be included as part of the inspection process which would lead to the school being granted their classification under the BC Independent Schools Act. Additionally, while falling outside of the originally study design, the work at VISII also presented a novel opportunity for future informal *ethnographic action*




research, a chance to observe how the tool was used in practice by a new group of educators and learners, while also experiencing its usage first-hand as a member of that community.

As this iteration of the assessment form was not simply focussed on math literacy, but instead on all eight of the PSII core competencies, one of the major requirements was that it be extended to assess competency development in the school more universally. While a daunting task, it was supported by updates to the PSII Competency Assessment Framework since 2016 (see Appendix E) which correlated stages of development (i.e., beginning, developing, expanding) to levels of Dr. Benjamin Bloom's *Taxonomy of Educational Objectives* (1958), providing *competency keywords* to associate with each stage of development (see Figure 11). Extending the dimensions of mastery from the mathematical competency model presented by Niss and Jensen (2011), these updates by the PSII team provided the requisite detail to reimagine the tool as a much more universally valuable competency assessment tool in K-12 education.

Figure 11.

Competency Keywords based on Bloom's Taxonomy

Learning Verbs and Approximate Depth

| | Verbs that describe learning activities at each level of depth | Level Name |
|---|---|----------------------|
|  | Arrange, define, describe, identify, label, recognize, recall, reproduce, select, repeat, duplicate, list, order, name, match, ... | Knowledge |
|  | Explain, convert, summarize, paraphrase, illustrate, classify, estimate, distinguish, express, give examples, infer, locate, select, rewrite, review, translate, discuss, ... | Comprehension |
|  | Use, compute, solve, demonstrate, apply, construct, change, dramatize, illustrate, interpret, manipulate, modify, predict, produce, relate, show, sketch, write, analyze, categorize, compare, contrast, | Application/Analysis |
| | Create, design, hypothesize (what if), invent, develop, arrange, assemble, collect and categorize, combine, compose, construct, devise, formulate, reconstruct, revise, rewrite, set up, synthesize, redevelop, | Synthesis |
| | Judge, recommend, critique, justify, appraise, argue, conclude, defend, discriminate, evaluate, interpret, predict, value, rate, | Evaluation |

Note. Competency depth learning verbs associated with depth of learning. Reprinted from *Learning Verbs* by PSII, n.d., Retrieved December 13, 2021, from <https://learningstorm.org/learning-verbs/>. Copyright by PSII. Used with Permission.

Unfortunately, with development paused since 2018, little work had been done to build on the mobile application concept. Fortunately, far more experience had been gained in using the more advanced features of Google Sheets. As such, this third iteration of the assessment form reimaged core aspects of the mobile application which could be applied through features in the Google Suite. In particular, this focussed on the aggregation of assessments and visualization of results. Retaining the single page design from the first Google Sheets form, Version 3 obfuscated more complex language originally found in the rubric into drop-down menus which populated automatically based on competency, removing the need for a separate reference document (see Figure 12). Furthermore, this new version removed the need for multiple rating scales per competency area, with the three continuums (one per dimension of mastery) unnecessary considering the new understanding of the development process according to Bloom (1956).

Figure 12.

Google Sheets Assessment Form: Version 3

| | | | | |
|--------------------|-----------------------|--------------|------------------|--|
| Type of Assessment | | Learner Name | | |
| Assessor Name | | Inquiry | | |
| Competency | Mathematical literacy | | | <div style="display: flex; justify-content: space-between;"> Developing Expanding Proficient Fluent </div> |
| Contexts | | | Assessment | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
| | | | Link to Artifact | |
| Indicators | | | Notes | |

- Asks questions of a mathematical nature
- Uses various strategies to approach a problem or situation
- Recognizes and uses patterns and relationships
- Makes sense of, relates, uses, and/or creates mathematical representations
- Uses symbolic, formal, and technical language
- Uses an understanding of context to guide the mathematical process
- Uses tools that may assist in implementing processes and procedures for determining mathematical solutions
- Understands the extents and limits of a mathematical solution

Noting far fewer ratings contributing to each assessment, and therefore an even greater necessity to obtain the multiple assessments to increase reliability (Castanelli et al., 2018; Gadbury Amyot et al., 2014) this iteration of the form also incorporated new information to support the decision making process through *competency indicators*. Developed by PSII, these indicators represented markers that could be used in determining both whether a competency had been demonstrated and to what depth. Using these easy-to-understand indicators and competency keywords as a type of *assessment scaffolding*, these new features made this iteration of the form much more practical, representing both the reference material and the assessment tool itself.

In addition to this scaffolding providing a more intuitive experience, it also allowed for the reporting to be much more granular, with the depth of competency development able to be extended through the indicators and contexts. This can be seen in the *Competency Development Snapshot* (see Figure 13) which presents not only depth, but the percentage of indicators observed, and in how many contexts. With the hypothesis that competency development should progress towards fluency across all contexts and including all indicators, this level of detail provides beneficial additional information for educators to use in guiding learner development.

Figure 13.

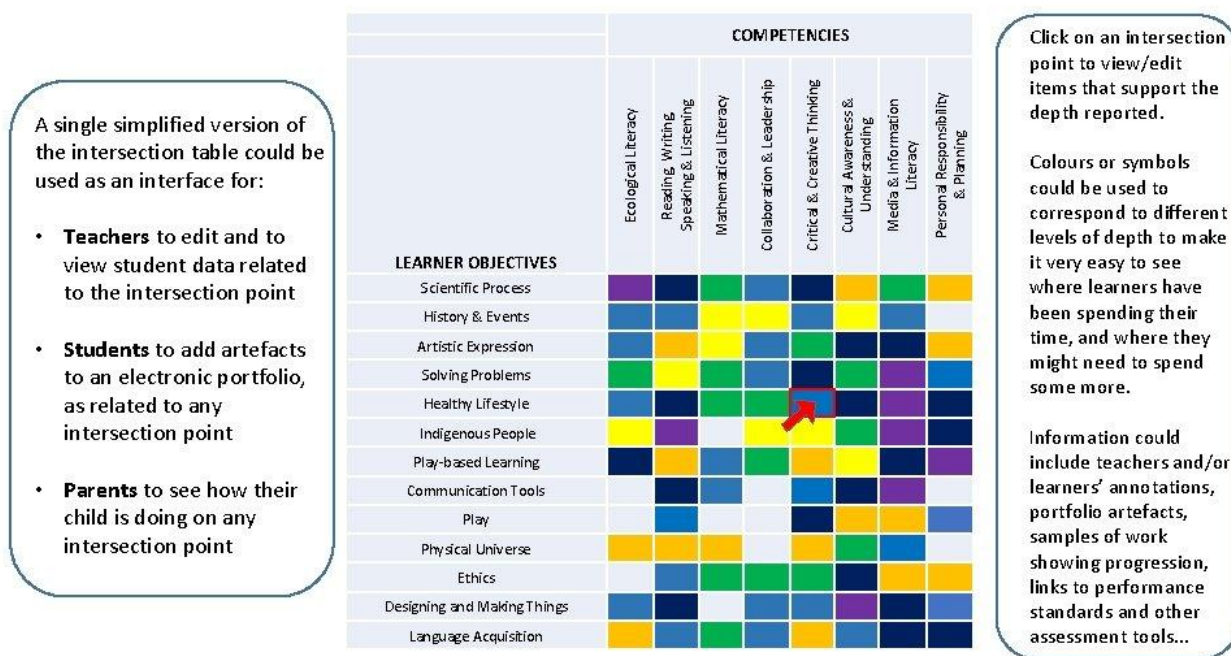
Sample Competency Development Snapshot Report

| Learner | John Lennon | COMPETENCIES | Comments | Goals | Assessments | Indicators | Contexts | Depth |
|---------------------|-------------|---|----------|----------------|-------------|------------|------------|-------|
| Total Assessments | 7 | Ecological literacy | | | 1 | 17% | 27% | |
| Educator-Assessment | 3 | READING, writing, speaking, and listening | | | 0 | 0% | 0% | |
| Self-Assessment | 1 | Reading, WRITING, speaking, and listening | | | 5 | 56% | 73% | |
| Peer-Assessment | 3 | Reading, writing, SPEAKING, and listening | | | 0 | 0% | 0% | |
| | | Reading, writing, speaking, and LISTENING | | | 0 | 0% | 0% | |
| DEPTH LEGEND | | Mathematical literacy | | | 0 | 0% | 0% | |
| | Developing | Collaboration and leadership | | | 0 | 0% | 0% | |
| | Expanding | Critical and creative thinking | | | 1 | 50% | 18% | |
| | Proficient | Cultural awareness and understanding | | | 0 | 0% | 0% | |
| | Fluent | Media and information literacy | | | 0 | 0% | 0% | |
| | | Personal planning and responsibility | | | 0 | 0% | 0% | |
| Created by: | | | | ANDREW MACLEAN | Date: | | 2021-12-12 | |

Further data to support learner progression towards competency came through the final reporting mechanism included as part of the new version of the form, a reimagining of the competency development report card presented in the 2015 PSII Graduation Framework Proposal (see Figure 14). A central component to this original PSII proposal (see Appendix E), the visual report card was intended to provide a more accessible way for all educational stakeholders (i.e., learners, parents and educators) to get a holistic view of a learner's progress towards graduation. This was accomplished through a single coloured cell representing the depth of development and understanding in each competency area across all of the contexts.

Figure 14.

PSII Proposed Competency Development Report Card



Note. PSII Competency Report Card. Reprinted from “Proposal for a New Prototype Graduation Program” by PSII, n.d., Retrieved December 13, 2021, from <https://slidetodoc.com/proposal-for-a-new-prototype-graduation-program-psii/>. Copyright by PSII. Used with Permission.

Implemented in the new version of the Google Sheet form as a real-time *competency mosaic*, this visualization compliments the *Competency Development Snapshot* report by literally highlighting areas where a student is finding success and where they need support. A practical example of how this could be used to guide learner growth is provided through the sample report in Figure 15. In this example, despite working across multiple contexts, it is evident that much of the learners' work has focussed on development of single competency: writing. As a result, an educator might recommend that this learner seek opportunities to develop in another competency area. To this end, the mosaic also identifies contexts which might be an accessible starting point for that development. In this learner's case, with *Artistic, Literary and Musical Expression and Appreciation* and *Designing and Making Things* evident areas of interest, those might be practical starting points for development in a competency area such as *Mathematical Literacy*.

Figure 15.

Sample Competency Development Mosaic Report Card

| Learner: | John Lennon | CONTEXTS | | | | | | | | | |
|---|------------------------------------|---|--|---|--|--------------------|----------------------------------|---------------------------|----------------------------------|-----------------------------|----------------------|
| COMPETENCIES | Scientific Process and Application | Significant Events and Figures in History | Artistic, Literary, and Musical Expression, and Appreciation | Identifying and Solving Problems and Making Decisions | Physical and Mental Health, Development, and Lifestyle | Indigenous Peoples | Structured and Unstructured Play | Explore Physical Universe | Ethics Awareness and Application | Designing and Making Things | Language Acquisition |
| | Ecological literacy | | | | | | | | | | |
| READING, writing, speaking, and listening | | | | | | | | | | | |
| Reading, WRITING, speaking, and listening | Blue | | Blue | Green | Blue | | Pink | Blue | | Blue | Blue |
| Reading, writing, SPEAKING, and listening | | | | | | | | | | | |
| Reading, writing, speaking, and LISTENING | | | | | | | | | | | |
| Mathematical literacy | | | | | | | | | | | |
| Collaboration and leadership | | | | | | | | | | | |
| Critical and creative thinking | | | Pink | | | | | | | Pink | |
| Cultural awareness and understanding | | | | | | | | | | | |
| Media and information literacy | | | | | | | | | | | |
| Personal planning and responsibility | | | | | | | | | | | |
| Comments | | | | | | | | | | | |
| Created by: | | ANDREW MACLEAN | | | | | Date: | | 2021-12-15 | | |

Summary of Chapter 4

This chapter reviewed the multi-year, iterative development process, building on the original *Learning Artifact Competency Assessment Form* utilized in the 2018 PSII study. Responding to challenges identified in the study findings, these data-driven revisions focussed on the production of an instrument which allowed for efficient aggregation of low-stakes assessments while also reducing complexity for individuals involved in the CBA process. Building on practical and aspirational ideations, the final version of the tool, created for VISII in 2021, took advantage of knowledge gained through practical classroom experience and independent updates to the proposed graduation framework at PSII. Through this experience and updates, it was possible to create a resource which could better support the vision and framework used at both PSII and VISII by providing a data-driven approach to guiding student progression along numerous competency continuums. Particularly considering the inclusion of visual reporting features, this 2021 version of the *Learning Artifact Competency Assessment Tool* seems to present as the most meaningful contribution this research has made to the field of educational assessment, with future CBA at multiple educational institutions potentially relying on its use.

Chapter 5: Summary and Reflection on Learning

There is a quote from American child psychologist Eileen Kennedy-Moore which says “The path of development is a journey of discovery that is clear only in retrospect, and it’s rarely a straight line” (Kennedy-Moore, 2011, p.6). Just as this is true for child development, so too was it true in my professional development, with the winding pathway of this project only recently demonstrating its true impact. In this chapter, I summarize the findings from the multi-faceted research process which began at PSII in 2016, exploring both the theory and practice behind the implementation of CBA in the new interdisciplinary, inquiry-based model of learning in the 21st century. Through a (i) review of findings from the literature, case study and lived experience, (ii) personal reflection, and (iii) recommendations for areas future research, this chapter seeks to close out this final stage of this research project, while also providing a solid starting point for any future iterations or classroom implementation of this novel assessment framework.

Revisiting Guiding Questions

This project sought to explore the development of an innovative competency assessment instrument which could be implemented within secondary education, allowing for an authentic evaluation of mathematical competency in a highly personalized and interdisciplinary learning environment. To this end, research focussed on four interrelated questions regarding mathematical literacy assessment in an interdisciplinary CBE environment. Specifically:

1. How can the assessment process in a highly-personalized and interdisciplinary K-12 learning environment be adjusted to incorporate competencies more efficiently?
2. What are the established best practices for assessment in competency-based education?
3. Are portfolios effective assessment tools for use in competency-based education?

4. What is an appropriate framework to assess mathematical competency?

While the first question would serve as the starting point for this research when it began back in 2016, considering the perspective gained upon further reflection, it is the three remaining questions which are first summarized below. These in turn lead to a final reflection on how they impacted the tool created to respond to the first—or in this case *final*—research question.

Best Practices for CBE

Best practices concerning CBA have evolved extensively since its early implementations in the 1970s, building on the primarily observational methods introduced by McClelland (1973) to now incorporate numerous types of evidence of learning in the determination of competence. Unfortunately, while these best practices are being used effectively in some post-secondary environments, the same cannot be said for K-12, where evidence from around the world has demonstrated a general lack of understanding concerning CBE and a corresponding lack of meaningful change to pedagogical practices (Klein et al., 1995; Komba & Mwandaji, 2015; Lestariani et al., 2018; Sadeq et al., 2020). What these findings demonstrate is the necessity to develop practical resources which support educators in gaining an understanding of how CBE works, while also applying this understanding in the classroom environment. Incorporating both of these needs, the tool that was developed for PSII and VISII through this project presents its significant value in implementing CBA best-practices in K-12 learning environments.

Effectiveness of Portfolios in CBE

With empirical evidence across educational contexts providing evidence to support the use of portfolios for assessment, their potential as impactful tools for CBA appears to be evident (Abidin & Walida, 2014; Byrne et al., 2009; Castanelli et al., 2018; Chang & Wu, 2012; Fourali,

1994; Gadbury-Amyot et al., 2014). That said, considering findings also indicating the necessity of multiple assessors to increase reliability (Gadbury-Amyot et al., 2014; Castanelli et al., 2018) and issues concerning time constraints in their valid implementation, effectiveness presents as a trifecta of considerations: validity, reliability and practicality. With this in mind, and considering the negative impact of complex assessment guidelines (Klein et al, 1995), it seems a key to improving the use of portfolios in CBE (at scale) is making the process as efficient as possible. By reducing the amount of interpretation an assessor must apply, scaffolding the assessment process, and simplifying reporting, the tool created for PSII and VISII as part of this research again presents its value towards improving the effectiveness of portfolios for CBA in K-12.

An Appropriate Framework for CBA in Math

While a review of scholarly literature identified multiple mathematical competency assessment frameworks for use in K-12 environments, considering its use in STEM related assessments administered seven times over the last 20 years in more than 80 countries, there seems to be the strongest support for the use of the OECD-PISA mathematical literacy assessment framework in secondary education (OECD, 2016). Certainly providing support for its inclusion in the assessment tool developed for the 2018 PSII study, the impact of this model goes far beyond mathematics, showcasing the multifaceted nature of competency development as it progresses through knowledge and understanding towards application and evaluation. Providing a practical way to apply this newfound knowledge concerning competency development, the assessment framework created for PSII and VISII through this project serves a dual role, supporting reporting and guidance of students in a competency-based K-12 environment.

Adjusting the CBA Process at PSII

Committed to enabling students to meet or exceed the BC graduation requirements, PSII's proposed graduation framework has always gone beyond the traditional subject-specific prerequisites as set out by the BC MOE, moving student assessment away from a checklist model towards a more valuable source of feedback for both student and educator. At the time of this study, however, one facet which was not yet fully implemented was an assessment resource to better support students in their progression towards competence along a continuum.

The original assessment instrument developed in 2018 responded to one aspect of this, providing a seemingly more scaffolded assessment process than the approaches which had previously been used at the school. Unfortunately, while providing more structure, this tool was ultimately an overcorrection, with the complexity resulting in a process which was cumbersome, time-consuming, and whose results demonstrated why similar implementations of portfolio assessment may have failed elsewhere in K-12. It did, however, provide a useful starting point for the development of the 2021 version of the tool, which presents a much higher potential to improve the effectiveness of portfolio assessment in highly-personalized learning environments. Removing the necessity to implement high-stakes summative assessments by aggregating frequent, low-stakes formative assessments, this tool supports educators in not only reporting on student learning but effectively identifying areas for future competency development.

Reflection on Learning and Personal Growth

When I began this research experience nearly six years ago, I was little more than a curious former youth worker with a passion for education, a drive to create, and a desire to understand how the learning which I had seen outside of school walls could contribute to student

success inside the traditional education system. Little did I realize how much I would need to learn about that complex system to gain such understanding, or what kind of a winding journey it would take to gain the perspective I needed to truly support the team at PSII in their important work. By far one of the most striking realizations, however, was just how critical the research project set out by PSII was to the field of curriculum and instruction in the 21st century, with their pivotal work in re-defining modern teaching still representing the cutting-edge of pedagogy in K-12 education even after so many years.

As a relative outsider to the field of curriculum and instruction in 2016, I entered this project with much the same view that many others have of assessment in the traditional K-12 and post-secondary educational system. This was one in which, despite being a feature of education which is challenging to some learners, the structures and rules in place concerning assessment were there to support an individual's development as they progress towards a successful future outside of the four walls of a school. Through this research, however, it has become evident that this idea of assessment presented to the outside world obscures the truth hidden just beneath the surface. This is a truth wherein, notwithstanding curricular reform mandates around the world, many educators still believe that the old ways are the best and therefore require additional evidence, support and understanding in order to shift their pedagogical practices for CBE.

When they submitted their proposal to the *K-12 Innovation Partnership* in 2015, PSII set out to accomplish a task which, upon deeper examination, it turned out had been addressed by many others before them. That was to build a portfolio-based assessment system which would support educators in adapting their practices for the high-personalized learning model of 21st century learning. What made their proposal unique was its move away from a focus on

summative assessments serving simply as a reporting mechanism, and instead as a descriptive tool to guide future learning. This move, while unique, however, was perhaps a more holistic interpretation of assessment. Finding its root in the latin *assidere* which means *to sit with*— their proposed changes served to support the perhaps more valuable understanding of assessment as “something we do *with* and *for* the student” rather than *to* them, by providing “helpful feedback, clearer expectations, enhanced motivation and better instruction” (Green, 1998, p.11).

Recommendations for Future Research

Considering the growing number of jurisdictions that are implementing CBE as part of K-12 educational reforms, and the increasing amount of time many schools have now been implementing CBE, there are three recommendations for future research related to this project. These include (i) long-term investigation into pedagogical changes related to assessment in K-12 CBE jurisdictions (ii) investigation into the use of the new version of the CBA instrument in an inquiry-based learning environment such as VISII and PSII, and (iii) investigation into the use of the new version of the CBA instrument in a more traditional K-12 learning environment.

The first of these recommendations for future research concerns investigation into the impact of long-term CBE in K-12. Firstly, looking at the impact on pedagogical practices, this additional research recognizes that, as with changes in any environment, there is a possibility that the necessary pedagogical adaptations required for CBE to be *successful* may just take longer to develop. Especially considering the relative successes in post-secondary environments where CBE has already seen significant adoption, it may also simply be a case of additional time required for the standards and practices to be translated for use in the K-12. Secondly, looking at the impact on educational outcomes, this additional research could include a longitudinal study

into the use of portfolios in CBE K-12 environments through a more scientific approach than was seen elsewhere. An example of this would be a study examining career outcomes as they relate to the use of portfolios K-12 CBE, following a control and treatment group to determine whether CBA portfolios actually have a positive impact in this respect.

The second recommendation for future research is related to the revised version of the CBA instrument. Following our initial study, we hypothesized that successful implementation of the 2018 version of the instrument might simply require a more long-term implementation and study. Further reflection, however, has presented evidence that it was not additional time which was required, but instead a creative re-imagining of the tool itself. Considering that the initial tool was hypothesized to present extreme value to the PSII education team—yet failed to do so—there is a demonstrable necessity to investigate the implementation of this new version of the tool into an inquiry-based learning environment. Unfortunately, many of the original study participants are no longer available to participate, thereby making it difficult to explore differences between the two versions of the tool at PSII. That said, the potential addition of VISII as a study location, and the continued presence of many of the PSII educators from the original study, presents the possibility for gathering extremely useful data regarding the implementation of this new version of the tool and framework across multiple time-periods, educational environments, and age-ranges.

The third and final recommendation for future research is to investigate the implementation of this new version of the CBA instrument in a more traditional K-12 environment in BC. While both PSII and VISII represent institutions required to meet BC government reporting mandates, as independent schools they have significantly more freedom in

their regular reporting as opposed to a middle or secondary school which is part of a public school district. As such, despite the value presented through the reporting features included in this new version of the form, future research would be necessary to not only examine whether formal *curricular content* could be incorporated, but also to extend the reporting features to display more course-specific measures such as level of understanding around curricular competencies, percentage of course completed, and final grade.

Representing a relative step backwards considering my newfound understanding of CBA, this final recommendation for future research may be by far the most important, with adoption of such an assessment model in many K-12 systems likely centering around the inclusion of content for many experienced educators. If remaining fundamentally focussed on the development of competencies, however, the result of this future research could be a tool which actively supports educators in their transition towards the use of innovative pedagogical practices which better align with CBE models and the future of education in the 21st century and beyond.

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Appendix A

PSII K-12 Innovation Partnership Proposal



British Columbia's

K-12 Innovation Partnership

Innovation Partnership Submission Form

OCTOBER, 2015

SUPPORTING INNOVATIVE TEACHING AND LEARNING PRACTICES IN SCHOOLS ACROSS BRITISH COLUMBIA

Thank you for submitting a proposal for the **K-12 Innovation Partnership**. Please complete the submission template below, which will ensure the Innovation Partnership Working Group has the information needed to fairly review each proposal.

Required Information

Proposal Title:

Inquiry-based, Interdisciplinary, Competency-based Graduation Structure: moving beyond translation to transformation

Please list the school(s) involved in the proposal:

Pacific School of Innovation and Inquiry

Key proposal contacts (Full name, title, and email address):

Jeff Hopkins, Principal Educator,
 Jake West, Educator,
 Jessica Asp, Educator,
 Rachel Mason, Educator,
 Ross Banister, Educator

Please identify the lead educator(s):

Jessica Asp

Identify up to two (2) key themes present in your proposal (i.e. Aboriginal education, project-based learning, cross-curricular, reporting and assessment, trades/skills training, etc.):

1. Inquiry-based
2. Reporting/Assessment/Graduation Credential

Please write a summary of your innovation proposal (*150 words maximum*):

These project summaries may be used on the Innovation Inventory website

We propose to develop and to demonstrate/share a new research-based structure that we hope to see become the way (or at least “a” way) for people to graduate from high school in BC. This proposal includes the building and deployment of an interdisciplinary, competency-based digital portfolio system that ties learning artifacts to competencies and contexts, allowing for integrated authentic assessment and reporting in a highly personalized learning



environment. We plan to see this system shared across BC and tested where people are ready and where BC policy/legislation allows.

Proposal Details

Please tell us more about your innovative program/practice. Please complete as many questions as possible, if they apply.

Please tell us which of the following aspects of innovation apply to your proposal, and briefly describe how they apply:

- | | |
|-------------------------------------|--------------------------|
| YES | NO |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> |

Teachers may still identify as specialists, but their day is only rarely organized by subject-based class. This is not necessary in all places who want to test the system, but it is the case in our school.

- | | |
|-------------------------------------|--------------------------|
| YES | NO |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> |

Much of what happens in a truly personalized environment is that learners are organized by interest, capacity, need, depth, and a variety of other characteristics that keep grouping dynamic.

- | | |
|-------------------------------------|--------------------------|
| YES | NO |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> |

Personalized learning requires that learning happen sometimes both in and outside the school building and the hours of instruction. Our learners may be learning outside of school and then curating their learning artifacts in school with teachers.

- | | |
|-------------------------------------|--------------------------|
| YES | NO |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> |

Teaching becomes entirely learner-centred. This means a need for flexibility, partnerships with other teachers and mentors, “just-in-time” lessons, and learning with the learners when their depth surpasses that of the teacher.

YES NO



- New partnerships

Personalized learning requires that the school walls become a semi-permeable membrane. Partnerships with local businesses and organizations, post-secondary, parents, and other community members and facilities is necessary.

Is this a new program or policy for your school(s)? If not, please identify how long it has been in place:

We have been operating in this way to some degree since we opened in 2013, but we hope to take it to a deeper level and to better share our findings with the rest of BC than we have had the capacity to do thus far.

Please explain how your innovation will benefit other schools across the province:

We hope to create the extra capacity required to share what we are doing deeply enough that aspects of it can be transferred to new contexts. Our goal as a school is to put ourselves out of business (recognizing that what we do is not more expensive than what mainstream schools do now and that the expertise and the will already exist in many places), and this partnership could help us do it.

Describe how your school district or independent school association is supporting this work:

We do not belong to an association or a district at this point.

Describe how your school does – or will – partner with other schools or networks, community organizations, etc. to share new learning challenges and successes:

Our goal is and has always been to live our own learning transparently. Because our goal is to help other schools and education jurisdictions to learn for us, we will continue to share what we do and what we learn from what we do. None of the products we create are now or would be proprietary beyond licensing under Creative Commons in order to prevent others from making profit on our work. Our efforts in sharing would be greatly enhanced with even a modest amount of funding to help defray the often overlooked costs associated with communicating the work in a meaningful and timely way. For that reason, we also hope this proposal can include a small amount of funding for this purpose.

Though everything we do now and propose to do in the future is research-based, these elements applied in combination have never been researched. We propose therefore that we be assisted in partnering with post-secondary researchers to look at the following subjects:

What indicators of learning are most valid and the most useful in a personalized, competency-based education system at the high school level?



What do post-secondary institutes need from the K to 12 system to have confidence in how to admit and place high school students who wish to attend those institutes upon graduation? Will our portfolio reporting proposal be sufficient? Could it begin to be used?

What qualitative research can be done to measure the impact of this approach to learning on individual learners? Sub-groups of learners?

What impact does this approach to learning have on teachers? Does the increased autonomy required in this system indicate a need for a change to teacher pre-service education?

Is there a significant difference in neurocognitive patterns associated with co-constructed, inquiry-based learning settings as opposed to top-down, universal content learning settings? This is by no means an exhaustive list of research questions, but rather a demonstration of some of the questions that could be explored. We would be happy to operate as a kind of learning laboratory – something that does not exist in BC the way it does in many other leading jurisdictions

Please explain how your initiative is improving learning for students:

We know from research over the past 30 to 40 years that education systems that recognize personal differences in learners and that allow for flexibility of context and content are always effective. Our initiative hopes to formalize that within a BC operating context in a way that can be adopted fairly easily. When learners are given agency to find ways to demonstrate their learning, not only does this improve the perceived locus-of-control (often reducing anxiety, depression, aggression), but it also helps motivate them to engage in their learning in a way that can no longer happen in a one-size-fits-all outcome-based curriculum.

What evidence are you using to assess success?

BC Education has always grappled with how to best measure success of the system. At the Graduation Program level, our exam system, while vastly improved over the years, is still in dissonance with modern concepts of learning and the assessment of learning. Though the elimination of Graduation Program exams is not part of our proposal, we would not consider exam results as indicative of success of an education model. Research tells us such exams do not say much about the quality of learning, and using as an indicator of success results on final exams that are neither fully standardized or that take into account the myriad ways in which learners can demonstrate the depth of their learning would be irresponsible research.

We plan to develop a strong set of indicators with post-secondary research partners, but in the meantime, we would consider a small set of data as evidence of the effectiveness of our model.

- a reduction in school-related anxiety;
- greater satisfaction among learners and parents
- greater satisfaction with learner ability in post-secondary settings
- greater satisfaction with learner ability in employment and community settings
- learner self-reports on depth of learning
- an unbiased external assessment of depth of learning in a random sample of learners as based on their portfolios



Please describe the breadth of your innovation (i.e. multiple classes, whole school, collaboration with other schools, cross-district, etc.):

Across school and across province (two levels).

Please describe how post-secondary research teams may help your innovation:

We think post-secondary teams can help as listed in previous sections of this form, but in summary:

- Identifying indicators of success
- Answering some burning research questions
- Measuring transferability of learners from secondary to post-secondary settings
- Observing and archiving the process
- Offering suggestions based on research

Please explain your willingness to take risks and learn from experiences:

We take appropriate but fairly large risks, especially when our actions are so strongly supported by research, by public voice, and and by personal conviction. We are happy to find both successes and failures in this initiative, as both will help us learn. We will, however, be careful that no harm comes to any of our learners.

Please describe how your community – inside and outside of the school – are involved and/or supportive of this innovation:

Please describe how you capture the diversity (voices, perspectives and experience) of students and teachers in this innovation:

This innovation is designed entirely to capture diversity in how people learn and demonstrate their learning. In addition, at several stage throughout the innovation, we will be checking in with our “stakeholders” to gather perspectives, comments on experience, and to answer questions – all of which will guide our practice. The main methods used to capture these voices will be face-to-face meetings (town hall style), online surveys, and through our daily face-to-face interactions with our learners and their families.

Does your innovation integrate the BC Aboriginal perspectives? Please explain:

Our innovation is absed on research that includes (and is perhaps most strongly based on) an indigenous pedagogy. Focusing on how we teach and learn (and not just content and universal processes and environments), what each person needs in their learning (as opposed to universal behavioural learning otucomes), and the recognition that different people need different curricular emphasis depending on



their existing competency and knowledge as well as their goals. We borrowed heavily from the work of both Dr. Martin Brokenleg and Dr. Gregory Cajete.

Does your innovation provide opportunities for collaborative professional learning? Please explain:

Our innovation requires constant, ongoing collaborative professional learning. We use a “scrum” methodology that involves regular check-ins, post-implementation retrospectives, and weekly “sprints” that are developed collaboratively and debriefed collaboratively in weekly stand-up meetings.

Please describe how your innovation aligns with curriculum changes taking place across the province:

Our innovation is aligned with a general statement of an intent to move toward personalized learning, including also inquiry-based learning methods, competency-based organization of learning content, and authentic assessment practices. We believe that our innovation will take us further down that road, especially in high school, than anything else we could think of. We hope to demonstrate what others can then take on more comfortably.

Please tell us about any consultations that have taken place with parents, community, First Nations, teachers, etc. regarding your innovation:

We have consulted extensively over the past four years with all of the parties mentioned above. We have not consulted with any local First Nations formally yet, but we have consulted with individual people from First Nations who are either members of our school community or who are experts in indigenous education, or both. We have begun a dialogue with a local First Nation that should deepen within the next two months.

How can the Innovation Partnership Working Group support your proposal?

The IPWG can help by letting us share our work as we go, offering suggestions about how we communicate results and findings, and about how we help to support other educators throughout the province. We hope that our teachers will be afforded an opportunity to be freed from the daily work at the school from time to time to be able to share our findings in writing, in person, and in various digital ways. This may include some funding to release our teachers from time to time. The IPWG can also support our proposal by helping to relax/eliminate/alter the policy/orders/legislation involved in making this proposed Graduation program one that can be used, at least in parallel to the current one, during the duration of our study.



Additional supporting materials (video links, presentation links, etc.) may be listed here:

You can look at our draft portfolio, based on the same foundations as the rest of our proposal, at <http://portfolio.learningstorm.org>. You can also watch our narrated powerpoint from just over a year ago explaining our original thoughts about how to transform BC's graduation program: https://www.youtube.com/watch?v=Rmw_kVX4lj4.

Would you like us to include information on your innovation on the K-12 Innovation Inventory?

Yes No

Need to tell us more?

If you would like to share more details with the Innovation Partnership Working Group, you may attach up to five (5) pages (single-sided) of supplemental information to your proposal. Additional content may include further details about your proposal, letters of support, presentation decks, etc.

Please note this supplemental information may not be reviewed in its entirety, so please ensure your key innovation information is included in this submission form.

Submission Sign-Off Checklist

- ✓ Have you included the appropriate sign-off sheet (public or independent school), with all applicable signatures outlined below? Please review this checklist and make sure you have the signatures you need, prior to sending us your submission. This checklist is not the sign-off form.
- ✓ In cases where a signature doesn't apply, please briefly tell us why. For example, some independent schools do not have a Superintendent; and some public schools do not have a local teacher union representative.
- ✓ Some projects may have more than one lead educator – in these cases, please identify a lead educator for sign-off purposes. You may also include a list with names and signatures of all educators involved.

Public School Sign-Off Checklist:



| | Yes | No | N/A | If no or N/A, please indicate why: |
|------------------------------------|--------------------------|--------------------------|--------------------------|---|
| Lead teacher | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Click here to enter text. |
| Principal | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Click here to enter text. |
| Local Teacher Union Representative | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Click here to enter text. |
| Local Union President | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Click here to enter text. |
| Superintendent | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Click here to enter text. |

Independent School Sign-Off Checklist:

| | Yes | No | N/A | If no or N/A, please indicate why: |
|--------------------------------|-------------------------------------|--------------------------|-------------------------------------|---|
| Lead educator | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Click here to enter text. |
| Principal/Head of School | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Click here to enter text. |
| Superintendent | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | We do not belong to a district. |
| Independent School Association | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | We do not belong to an association. |

Important Note:

All applicable signatures must be collected prior to submitting your proposal to the IPWG. Submissions missing the applicable signatures will not be considered.

If you have questions about sign-off requirements, please contact:

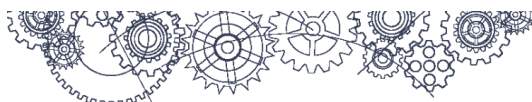
Katie McLaughlin, Manager
 K-12 Innovation Partnership Secretariat
 Email: Katie.McLaughlin@gov.bc.ca
 Phone: 250-818-1292



Appendix B

BC Dogwood Diploma Graduation Requirements Checklist

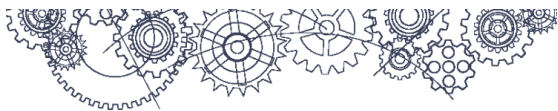
(Government of British Columbia, 2021)



GRADUATION REQUIREMENTS

Graduation Requirements (Dogwood Diploma)

| Summary of Graduation Requirements: Dogwood Diploma | | | |
|---|--|--|--|
| | Grade 10 | Grade 11 | Grade 12 |
| Required: minimum 52 credits | | | |
| English Language Arts | Choose two 2-credit courses: <input type="checkbox"/> Composition 10 <input type="checkbox"/> Creative Writing 10 <input type="checkbox"/> Literary Studies 10 <input type="checkbox"/> New Media 10 <input type="checkbox"/> Spoken Language 10 <input type="checkbox"/> EFP Writing 10 <input type="checkbox"/> EFP Literary Studies 10 <input type="checkbox"/> EFP New Media 10 <input type="checkbox"/> EFP Spoken Language 10 | Choose one 4-credit course: <input type="checkbox"/> Composition 11 <input type="checkbox"/> Creative Writing 11 <input type="checkbox"/> Literary Studies 11 <input type="checkbox"/> New Media 11 <input type="checkbox"/> Spoken Language 11 <input type="checkbox"/> EFP Literary Studies and Writing 11 <input type="checkbox"/> EFP Literary Studies and New Media 11 <input type="checkbox"/> EFP Literary Studies and Spoken Language 11 | Choose one 4-credit course: <input type="checkbox"/> English Studies 12 <input type="checkbox"/> English First Peoples 12 |
| Mathematics | Choose one 4-credit course: <input type="checkbox"/> Foundations of Mathematics and Pre-calculus 10 <input type="checkbox"/> Workplace Mathematics 10 | Choose one 4-credit course: <i>(Grade 11 or Grade 12)</i> <input type="checkbox"/> Foundations of Mathematics 11 <input type="checkbox"/> Pre-calculus 11 <input type="checkbox"/> Workplace Mathematics 11 <input type="checkbox"/> History of Mathematics 11 <input type="checkbox"/> Computer Science 11 | <input type="checkbox"/> Foundations of Mathematics 12 <input type="checkbox"/> Apprenticeship Mathematics 12 <input type="checkbox"/> Pre-calculus 12 <input type="checkbox"/> Calculus 12 <input type="checkbox"/> Geometry 12 <input type="checkbox"/> Statistics 12 <input type="checkbox"/> Computer Science 12 |
| Science | Required 4-credit course: <input type="checkbox"/> Science 10 | Choose one 4-credit course: <i>(Grade 11 or Grade 12)</i> <input type="checkbox"/> Physics 11 <input type="checkbox"/> Life Sciences 11 <input type="checkbox"/> Chemistry 11 <input type="checkbox"/> Earth Sciences 11 <input type="checkbox"/> Science for Citizens 11 <input type="checkbox"/> Environmental Science 11 | <input type="checkbox"/> Physics 12 <input type="checkbox"/> Anatomy and Physiology 12 <input type="checkbox"/> Chemistry 12 <input type="checkbox"/> Geology 12 <input type="checkbox"/> Environmental Science 12 <input type="checkbox"/> Specialized Science 12 |
| Social Studies | Required 4-credit course: <input type="checkbox"/> Social Studies 10 | Choose one 4-credit course: <i>(Grade 11 or Grade 12)</i> <input type="checkbox"/> Explorations in Social Studies 11 <input type="checkbox"/> Francophone History and Culture 11 | <input type="checkbox"/> B.C. First Peoples 12 <input type="checkbox"/> Contemporary Indigenous Studies 12 <input type="checkbox"/> Comparative Cultures 12 <input type="checkbox"/> Comparative World Religions 12 <input type="checkbox"/> Economic Theory 12 <input type="checkbox"/> Human Geography 12 <input type="checkbox"/> Physical Geography 12 <input type="checkbox"/> Urban Studies 12 <input type="checkbox"/> 20th Century World History 12 <input type="checkbox"/> Asian Studies 12 <input type="checkbox"/> Genocide Studies 12 <input type="checkbox"/> Political Studies 12 <input type="checkbox"/> Law Studies 12 <input type="checkbox"/> Philosophy 12 <input type="checkbox"/> Social Justice 12 |



GRADUATION REQUIREMENTS

| Summary of Graduation Requirements: Dogwood Diploma | | | |
|---|---|--|---|
| | Grade 10 | Grade 11 | Grade 12 |
| Arts Education/ADST | Choose 4 credits at either <i>Grade 10, Grade 11, or Grade 12</i> <input type="checkbox"/> Arts Education (see Table on page 28) <input type="checkbox"/> Applied Design, Skills, and Technologies (ADST) (see Table on page 29) | | |
| Career Education | Required 8 credits in Career Education (Grade 10, Grade 11, or Grade 12) <input type="checkbox"/> Career-Life Education <input type="checkbox"/> Career-Life Connections (including 30 hours of work experience or career-life exploration) | | |
| Physical and Health Education (PHE) | Required 4-credit course: <input type="checkbox"/> Physical and Health Education 10 | | |
| Electives: minimum 28 credits | | | |
| Depending on the school's offerings and student's choice, the number of electives in each Grade level will vary. The 28 elective credits in Grades 10-12 can come from the following options: <ul style="list-style-type: none"> • Ministry-developed or Ministry-approved courses • Post-Secondary ("dual") credit • Board/Authority Authorized (BAA)/First Nation Authorized (FNA) courses • External Credentials • Independent Directed Studies (IDS) | | | |
| Elective Courses | Grade 10: 2-5 electives <ul style="list-style-type: none"> • _____ • _____ • _____ • _____ • _____ | Grade 11: 3-5 electives <ul style="list-style-type: none"> • _____ • _____ • _____ • _____ • _____ | Grade 12: 6-8 electives* <ul style="list-style-type: none"> • _____ • _____ • _____ • _____ • _____ |
| Total: 80 credits required for graduation | | | |
| *at least 16 credits must be at the Grade 12 level, including a required Grade 12 Language Arts course. | | | |
| Graduation Program Assessments | | | |
| Required for Graduation | <input type="checkbox"/> Grade 10 Numeracy <input type="checkbox"/> Grade 10 Literacy | | <input type="checkbox"/> Grade 12 Literacy Beginning in the 2021/22 school year. |

Appendix C

Annotated Mathematical Competency Assessment Rubrics

| Annotated Mathematical Competency Rubric - Formulating | | | | |
|---|--|--|---|--|
| | Formulating situations mathematically | What does that mean? | Examples assessment questions: | |
| Communicating | Read, decode, and make sense of statements, questions, tasks, objects or images, in order to form a mental model of the situation | How deeply/completely is the learner understanding a question or situation? Can they take that understanding and hold a mental picture of it? Can they describe that understanding or picture? | <ul style="list-style-type: none"> · What is this problem about? · What are the critical components of this problem? · What is a similar problem to this? · How would you describe this to ____? | |
| Mathematizing | Identify the underlying mathematical variables and structures in the real world problem, and make assumptions so that they can be used | How well can the learner identify or attribute the "math" in a problem? How well can the learner describe the patterns, numbers, relationships, or shapes in the problem or situation? | <ul style="list-style-type: none"> · What (patterns/numbers/relationships/shapes) help to define this problem? | |
| Representation | Create a mathematical representation of real-world information | How is the learner able to express the problem in a mathematical context? Is there a clear model, formula, or description that the learner can express? | <ul style="list-style-type: none"> · How can you express this problem? · How can you express the context of this problem? | |
| Reasoning and Argument | Explain, defend or provide a justification for the identified or devised representation of a real-world situation | How well can the learner describe how and why they are approaching a problem in a certain way? | <ul style="list-style-type: none"> · What have you done? · Why have you done it this way? | |
| Devising Strategies for solving problems | Select or devise a plan or strategy to mathematically reframe contextualised problems | How comprehensively or deeply is the learner formulating problem solving strategies? | <ul style="list-style-type: none"> · How will this (help you) solve the problem? · How do you know? · How did you come to this decision? | |
| Using symbolic, formal and technical language | Use appropriate variables, symbols, diagrams and standard models in order to represent a real-world problem using symbolic/formal language | How is the learner using formal (academic) mathematical writing? How comprehensively can they explain what the symbols mean and do? | <ul style="list-style-type: none"> · What is happening in this problem? · How do you write down what you are doing in a math equation/formula/problem? · What does (such and such) a symbol mean? When would you use it? | |
| Using mathematical tools | Use mathematical tools in order to recognise mathematical structures or to portray mathematical relationships | How is the learner using formal mathematics to express or understand situations? How can the student express understanding using formal math? | <ul style="list-style-type: none"> · Show how you might express this situation using math. · Looking at this problem, what can you tell me about it mathematically. · What tools did you use to solve/describe....? | |

| Annotated Mathematical Competency Rubric - Employing | | | |
|---|---|--|---|
| | Employing mathematical concepts, facts, procedures and reasoning | What does that mean? | Examples assessment questions: |
| Communicating | <p>Articulate a solution, show the work involved in reaching a solution and/or summarize and present intermediate mathematical results</p> | <p>What was the learner's process? What was the learner's understanding of the process?</p> | <ul style="list-style-type: none"> · What does this answer mean? · Does this answer make sense? Why? · How does your process support arriving at a solution? |
| Mathematizing | <p>Use an understanding of the context to guide or expedite the mathematical solving process, e.g. working to a context-appropriate level of accuracy</p> | <p>What (mathematical) tools is the learner using to solve or describe the problem? What reasons are there for using this tool?</p> | <ul style="list-style-type: none"> · Why did you choose/develop this process? · What does this process allow you to understand/conclude? · How do you know when you are done? |
| Representation | <p>Make sense of, relate and use a variety of representations when interacting with a problem</p> | <p>What ways does the learner represent the problem? What does the learner understand or interpret by this problem? What tools are used to present the problem?</p> | <ul style="list-style-type: none"> · Does the outcome change with a different process or criteria? · How else could you describe this problem/solution? · What did you use to solve this problem? |
| Reasoning and Argument | <p>Explain, defend or provide a justification for the processes and procedures used to determine a mathematical result or solution Connect pieces of information to arrive at a mathematical solution, make generalisations or create a multi-step argument</p> | <p>What ways did the learner have to verify/test their conclusions? Was there experimentation that informed the learner's reasoning or created change in the problem/solution/process?</p> | <ul style="list-style-type: none"> · What did you do? · Why did you do it? · Would you do it again? · How might you do it differently? |
| Devising Strategies for solving problems | <p>Activate effective and sustained control mechanisms across a multi-step procedure leading to a mathematical solution, conclusion or generalisation</p> | <p>What strategies does the learner use to approach solutions? Are there certain controls/variables that the learner employs to achieve understanding?</p> | <ul style="list-style-type: none"> · What variables/components were you controlling for? · How did you come to choose/develop this process? · What (aspect of this) problem were you working to solve? |
| Using symbolic, formal and technical language | <p>Understand and utilise formal constructs based on definitions, rules and formal systems as well as employing algorithms</p> | <p>What formulas and procedures (algorithms) does the learner understand? What formulas and procedures (algorithms) does the learner use? What rules has the learner internalized?</p> | <ul style="list-style-type: none"> · What formula/procedure are you using? · How does that formula/procedure work? · Why are you using this process? · Is there another formula/process that you could use? · What are the limitations of the process you are using? |
| Using mathematical tools | <p>Know about and be able to make appropriate use of various tools that may assist in implementing processes and procedures for determining mathematical solutions</p> | <p>What tools does the learner use when faced with new or novel problems? What processes does the learner use in new situations?</p> | <ul style="list-style-type: none"> · How would you approach this problem? · What clues/indicators inform your decisions? · How do you know if it is working? · What constitutes a solution? |

| Annotated Mathematical Competency Rubric - Interpreting, Applying & Evaluating | | | |
|---|---|--|---|
| | Interpreting, applying and evaluating mathematical outcomes | What does that mean? | Examples assessment questions: |
| Communicating | Construct and communicate explanations and arguments in the context of the problem | How fully (deeply) does the learner's explanation of the problem address the context of the problem? How fully does the learner's communication or argument of the solution consider the context? | <ul style="list-style-type: none"> · Talk about what is going on with this problem. · Talk about your solution. · How does the context of this problem inform your solution? |
| Mathematizing | Understand the extent and limits of a mathematical solution that are a consequence of the mathematical model employed | How does the learner recognize the patterns or formulas that lead to a solution? What limits does this place on the solution? How do different patterns lead to different outcomes? | <ul style="list-style-type: none"> · What does this solution mean? · What is required for this solution? · What assumptions are implicit/explicit in this solution? · What changes if the situation changes? |
| Representation | Interpret mathematical outcomes in a variety of formats in relation to a situation or use; compare or evaluate two or more representations in relation to a situation | What different methods or formats does the learner express their solution in? How do the results compare? How does the learner change their solution in relation to context? | <ul style="list-style-type: none"> · Why have you presented your ideas in this way? · How might a different context change this problem/solution? · Justify the used of the representation you employed. |
| Reasoning and Argument | Reflect on mathematical solutions and create explanations and arguments that support, refute or qualify a mathematical solution to a contextualised problem | How does the learner explain their process? What indicators does the learner use to defend their process or answer? How does the learner describe the context? | <ul style="list-style-type: none"> · Why did you do what you did? · Would you do it again? · What if the context changed? · How do you know? |
| Devising Strategies for solving problems | Devise and implement a strategy in order to interpret, evaluate and validate a mathematical solution to a contextualised problem | What is the learner's process for making sense of a solution? What elements of their plan or strategy does the learner consider and address? How do they interpret and apply the results? | <ul style="list-style-type: none"> · What was/is your plan for this problem? · What will the results mean? · What other ways could you come to this solution? · What are the alternative interpretations? |
| Using symbolic, formal and technical language | Understand the relationship between the context of the problem and representation of the mathematical solution. Use this understanding to help interpret the solution in context and gauge the feasibility and possible limitations of the solution | How does the learner describe the relationship between the problem and the solution? How does the learner describe the meaning of the solution? How is the learner understanding/employing formal math symbols in both the problem and the solution? | <ul style="list-style-type: none"> · Describe the relationship between the problem, the solution, and the context. · What does the solution imply? · What do the symbols imply? · How have the symbols added to your understanding of the problem and solution? |
| Using mathematical tools | Use mathematical tools to ascertain the reasonableness of a mathematical solution and any limits and constraints on that solution, given the context of the problem | Does the answer seem reasonable or accurate to the learner? How does the learner assess the reasonableness or accuracy of the solution? Does the learner identify any limits to the possible solutions? | <ul style="list-style-type: none"> · Based on the methods used, what are the limits, if any, associated with the solution? · What lets you know the solution is reasonable? · What tools did you use to ascertain reasonability? |

Appendix D

University of Victoria Human Ethics Application



Office of Research Services | Human Research Ethics Board
 Michael Williams 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 Approval

| | |
|--|---------------------------------------|
| PRINCIPAL INVESTIGATOR: Andrew MacLean | ETHICS PROTOCOL NUMBER: 17-484 |
| UVic STATUS: Master's Student | Minimal Risk Review - Delegated |
| UVic DEPARTMENT: EDCI | ORIGINAL APPROVAL DATE: 31-Jan-18 |
| SUPERVISOR: Dr. Todd Milford | APPROVED ON: 31-Jan-18 |
| | APPROVAL EXPIRY DATE: 30-Jan-19 |
| PROJECT TITLE Mathematical Competency Assessment in Secondary Education | |
| RESEARCH TEAM MEMBERS Co-Investigators: Todd Milford (UVic), Ulrike Stege (UVic); School Lead: Jessica Asp (Pacific School of Innovation & Inquiry) | |
| DECLARED PROJECT FUNDING: None | |
| CONDITIONS OF APPROVAL | |
| This Certificate of Approval is valid for the above term provided there is no change in the protocol. | |
| <p>Modifications 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>Renewals 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>Project Closures 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> | |
| Certification | |
| 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. | |
| <hr/> Dr. Rachael Scarth Associate Vice-President Research Operations | |

Certificate Issued On: 31-Jan-18

17-484 MacLean, Andrew



**University
of Victoria**

**Human Research Ethics Board
Application for Research Ethics Approval for
Human Participant Research**

**The following application form is an institutional protocol based on the
Tri-Council Policy Statement on the Ethical Conduct for Research Involving Humans**

Instructions:

1. Download this application and complete it on your computer. Hand written applications will not be accepted. You will receive a response from the HREB within 4-6 weeks.
2. Use the *Human Research Ethics Board Annotated Guidelines* to complete this application:
<http://www.uvic.ca/research/conduct/home/regapproval/humanethics/index.php>.
Note: This form is linked to the guidelines. Access links in blue text by hitting CTRL and clicking on the blue text.
3. Submit one (1) original and two (2) copies of this completed, signed application with all attachments to: Human Research Ethics, Michael Williams Building (MWB), Room B202, University of Victoria, PO Box 1700 STN CSC, Victoria BC V8W 2Y2 Canada
4. Do not staple the original copy (clips O.K.).
5. If you need assistance, contact the Human Research Ethics Office at (250) 472-4545 or ethics@uvic.ca
6. Please note that applications are screened and will not be entered into the review system if incomplete (e.g., missing required attachments, signatures, documents). You will be notified in this case.
7. Once approved, a Request for Annual Renewal must be completed annually for on-going projects for continuing Research Ethics approval.

A. Principal Investigator

If there is more than one Principal Investigator, provide their name(s) and contact information below in Section B, Other Investigator(s) & Research Team.

Last Name: **MacLean**

First Name: **Andrew**

Department/Faculty: **Curriculum and Instruction**

UVic Email:

Phone:

Primary Email: :

Mailing Address (if different from Department/Faculty) including postal code:

**REVISED
JAN 29 2018**

Title/Position: (Must have a UVic appointment or be a registered UVic student)

- Faculty Undergraduate Ph.D. Student
 Staff Master's Student Post-Doctoral
 Adjunct or Sessional Faculty (Appointment start and end dates): _____

Students: Provide your Supervisor's information:

Name: **Dr. Todd Milford**

Email:

Department/Faculty: **Curriculum and Instruction**

Phone:

Graduate Students: Provide your Graduate Secretary's email address: edcigrad@uvic.ca

All PIs: Provide any additional contacts for email correspondence:

Name: **Dr. Ulrike Stege**

Email:

Name:

Email:

| | | |
|--|------------------------|--------------------|
| FOR HUMAN RESEARCH ETHICS' USE ONLY | | Protocol No. _____ |
| HREB Chair Approval Signature: _____ | | Date: _____ |
| Annual Renewal Due: _____ | Approval/Expiry: _____ | |

B. Project InformationProject Title: **Mathematical Competency Assessment in Secondary Education**Anticipated Start Date for Recruitment / Data Collection: **1 Feb 18** Anticipated End Date: **31 Mar 18**Geographic location(s) of study: **Victoria, BC**

Participant recruitment/data collection location(s)/site(s):

Keywords: 1. **Mathematics** 2. **Assessment** 3. **Competency** 4. **Grades 9-12**Is this application connected/associated/linked to one that has been recently submitted? Yes No

If yes, provide further information:

All Current Investigator(s) and Research Team:

(Include all current co-investigators, students, employees, volunteers, community organizations.)

| Contact Name | Role in Research Project | Institutional Affiliation | Email or Phone |
|---------------------|--------------------------|---|----------------|
| Todd Milford | Co-Investigator | University of Victoria | |
| Ulrike Stege | Co-Investigator | University of Victoria | |
| Jessica Asp | School Lead | Pacific School of Innovation & Inquiry | |

For Faculty Only: Any Graduate Student Research Assistants who will use the data to fulfill UVic thesis/ dissertation/ academic requirements: Include all current Graduate Student Research Assistants

| Student/Research Assistant | Email or Phone |
|----------------------------|----------------|
| | |

C. Multi-Jurisdictional ResearchDoes the proposed project require Research Ethics Board (REB) approval from another research ethics board(s)? Yes No

If yes, list the other research ethics board from which you or research team members have sought approval or will seek approval:

(Attach proof of having applied to other research ethics board(s). Please forward approvals upon receiving them. Be assured that UVic ethics approval may be granted prior to receipt of other research ethics board approvals.)

If you have answered "yes" above, please indicate your role in the multi-jurisdictional research project (Check all that apply):

- Recruiting participants
- Collecting data
- Analyzing data (with or without identifiers) collected by you and/or UVic research team members
- Analyzing data that *contains* identifiers: Data to be collected by non-UVic research team members as outlined in this application.
- Analyzing data that *does not* contain identifiers: Data to be collected by non-UVic research team members as outlined in this application.
- Dissemination of results via publications, reports, conferences, internet, etc.

Other (explain):

D. Agreement and Signatures

For further information, on signature requirements, please see the [Guidelines for Signatures](#).

Principal Investigator and Student Supervisor affirm that:

- I have read this application and it is complete and accurate.
- The research will be conducted in accordance with the University of Victoria regulations, policies and procedures governing the ethical conduct of research involving human participants and all relevant sections of the TCPS 2.
- The conduct of the research will not commence until ethics approval has been granted.
- The researcher(s) will seek further HREB review if the research protocol is modified.
- Adequate supervision will be provided for students and/or staff.

Principal Investigator

Student's Supervisor or co-Supervisor (for student applicants only)

Signature

Signature

Andrew MacLean

Print Name

Dr. Ulrike Stege

Print Name

23 November 2017

Date

23 November 2017

Date

Chair, Director or Dean

(To be signed by the person to whom the PI, or student's supervisor reports, and must not be the same person as the PI or student's supervisor. The Research Ethics Office cannot accept applications with duplicate signatures)

I affirm that adequate research infrastructure is available for the conduct and completion of this research.

Signature

Print Name

Date

E. Project Funding

Have you applied for funding for this project? Yes No If yes, please complete the following:

| Source of Project Funding | Funding Applied | Funding Approved | Project Title Used in Funding Application (or additional information) |
|---------------------------|------------------------------|------------------------------|---|
| | <input type="checkbox"/> Yes | <input type="checkbox"/> Yes | |
| | <input type="checkbox"/> No | <input type="checkbox"/> No | |
| | <input type="checkbox"/> Yes | <input type="checkbox"/> Yes | |
| | <input type="checkbox"/> No | <input type="checkbox"/> No | |
| | <input type="checkbox"/> Yes | <input type="checkbox"/> Yes | |

Other (explain):

D. Agreement and Signatures

For further information, on signature requirements, please see the Guidelines for Signatures.

Principal Investigator and Student Supervisor affirm that:

- I have read this application and it is complete and accurate.
- The research will be conducted in accordance with the University of Victoria regulations, policies and procedures governing the ethical conduct of research involving human participants and all relevant sections of the TCPS 2.
- The conduct of the research will not commence until ethics approval has been granted.
- The researcher(s) will seek further HREB review if the research protocol is modified.
- Adequate supervision will be provided for students and/or staff.

Principal Investigator

Student's Supervisor or co-Supervisor (for student applicants only)

Signature

Signature

Andrew MacLean
Print Name

Dr. Ulrike Stege
Print Name

23 November 2017
Date

23 November 2017
Date

Chair, Director or Dean

(To be signed by the person to whom the PI, or student's supervisor reports, and must not be the same person as the PI or student's supervisor. The Research Ethics Office cannot accept applications with duplicate signatures)

I affirm that adequate research infrastructure is available for the conduct and completion of this research.

Signature

Print Name

Date

E. Project Funding

Have you applied for funding for this project? Yes No If yes, please complete the following:

| Source of Project Funding | Funding Applied | Funding Approved | Project Title Used in Funding Application (or additional information) |
|---------------------------|---|---|---|
| | <input type="checkbox"/> Yes <input type="checkbox"/> No | <input type="checkbox"/> Yes <input type="checkbox"/> No | |
| | <input type="checkbox"/> Yes <input type="checkbox"/> No | <input type="checkbox"/> Yes <input type="checkbox"/> No | |
| | <input type="checkbox"/> Yes | <input type="checkbox"/> Yes | |

HRE Revised March 2017

| | | | |
|--|------------------------------|------------------------------|--|
| | <input type="checkbox"/> No | <input type="checkbox"/> No | |
| | <input type="checkbox"/> Yes | <input type="checkbox"/> Yes | |
| | <input type="checkbox"/> No | <input type="checkbox"/> No | |

Will this project receive funding from the US *National Institutes of Health (NIH)*?

Yes No

If yes, provide further information:

If you have applied for funding, have you submitted a funding application or contract notification to the UVic Office of Research Services?

Yes No

F. Scholarly Review

What type of scholarly review has this research project undergone?

- External Peer Review (*e.g., granting agency*)
- Supervisory Committee or Supervisor—required for all student research projects
- None
- Other, please explain:

G. Other Approvals and Consultations

Do you require additional approvals or consultations from other agencies, community groups, local governments, etc.?

Yes, attached Yes, will forward as received No

(Attach proof of having made request(s) for permission, or attach approval letter(s). Please forward approvals upon receiving them. Be assured that ethics approval may be granted prior to receipt of external approvals.)

If **Yes**, please check all that apply:

School District, Superintendent, Principal, Teacher. Please list the school districts or schools:

PSII (PSII)

BC Health Authorities and/or BC Universities. Check all that apply:

- Island Health (VIHA)
- Interior Health (IH)
- Vancouver Coastal Health (VCH)
- Northern Health (NH)
- Fraser Health (FH)
- Simon Fraser University
- University of BC
- BC Cancer Agency
- Children's & Women's Hospital
- Providence Health Care
- University of Northern BC

If you are UVic faculty, student or staff and will be conducting research under the auspices of any of the institutions listed above, (involving staff, patients, health records, sites and/or recruitment through their sites, including recruitment via poster

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placement), your application may be reviewed under the *BC Ethics Harmonization Initiative*. (a single coordinated review with the other institution(s) listed). Harmonization also applies when members of your research team consist of faculty, staff and students from the BC institution(s) listed above. Please contact ethics@uvic.ca, 250-472-4545 if you have questions about a harmonized review.

Please explain:

- Other regional government authority, please explain:
- Community Group (e.g., formal organization, informal collective), please explain:
- Other Research Ethics Board (REB) Approval, please explain:
- UVic Biosafety Committee Approval. Attach your Biosafety Approval, or your correspondence with the *Biosafety Committee*, to this application. Note that Research Ethics Approval is contingent on Biosafety Approval.
- Other Approval, please explain:

H. Researcher(s) Qualifications

In light of your research methods, the nature of the research, and the characteristics of the participants, what training, qualifications, or personal experiences do you and/or your research team have (e.g., research methods course, language proficiency, committee expertise, training on the equipment to be used)?

Dr. Todd Milford is an Associate Professor in Science Education and Research Methodologies in the Department of Curriculum and Instruction at the University of Victoria. Dr. Milford holds a Bachelor of Science and a Bachelor of Education as well as a Master of Education in Special Education and a PhD in Measurement and Evaluation. Dr. Milford has an active research agenda and publishes regularly in the areas of Educational Assessment and Quantitative Methods.

Dr. Ulrike Stege is an Associate Professor and Chair of the Department of Computer Science at the University of Victoria. Dr. Stege holds a Diploma in Mathematics from the University of Freiburg and a Doctorate in Computer Science from ETH Zurich. In addition to her research in parameterized complexity and algorithm development research, Dr. Stege is interested in interdisciplinary research including human problems solving and K-12 instructional pedagogy.

Mr. Andrew MacLean is an educator with more than 10 years' experience developing and delivering curriculum in learning environments across the country. Currently a Graduate Student in the Department of Curriculum and Instruction at the University of Victoria, Andrew most recently served as the Director of Science Venture, an award-winning Science, Technology, Engineering and Math outreach program run by Faculty of Engineering at the University of Victoria.

I. Research Involving Aboriginal Peoples of Canada (Including First Nations, Inuit and Métis)

The TCPS 2 (Chapter 9) highlights the importance of community engagement and respect for community customs, protocols, codes of research practice and knowledge when conducting research with Aboriginal peoples or communities. "Aboriginal peoples" includes First Nations, Inuit and Métis regardless of where they reside or whether or not their names appear on an official register. The nature and extent of community engagement should be determined jointly by the researcher and the relevant community or collective, taking into account the characteristics and protocols of the community and the nature of the research.

1. Conditions of the Research

- 1a. Will the research be conducted on (an) Aboriginal – First Nations, Inuit and Métis – lands, including reserves, Métis settlement, and lands governed under a self-government agreement or an Inuit or First Nations land claims agreement?

No

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 Yes, provide details:

- 1b. Do any of the criteria for participation include membership in an Aboriginal community, group of communities, or organization, including urban Aboriginal populations?

 No Yes, provide details:

- 1c. Does the research seek input from participants regarding a community's cultural heritage, artifacts, traditional knowledge or unique characteristics?

 Yes No

- 1d. Will Aboriginal identity or membership in an Aboriginal community be used as a variable for the purposes of analysis?

 Yes No

- 1e. Will the results of the research refer to Aboriginal communities, peoples, language, history or culture?

 Yes No

2. Community Engagement

- 2a. If you answered "yes" to questions a), b), c), d) or e), have you initiated or do you intend to initiate an engagement process with the Aboriginal collective, community or communities for this study?

 Yes No

- 2b. If you answered "yes" to question 2a, describe the process that you have followed or will follow with respect to community engagement. Include any documentation of consultations (*i.e. formal research agreement, letter of approval, email communications, etc.*) and the role or position of those consulted, including their names if appropriate:

3. No community consultation or engagement

If you answered "no" to question 2a, briefly describe why community engagement will not be sought and how you can conduct a study that respects Aboriginal communities and participants in the absence of community engagement.

J. International Research

4. Will this study be conducted in a country other than Canada?

 Yes No

If yes, describe how the laws, customs and regulations of the host country will be addressed (*consider research Visas, local Institutional Research Ethics Board requirements, etc.*):

K. Description of Research Project

REVISED
JAN 29 2018

5. Purpose and Rationale of Research

Briefly describe in non-technical language:
Please use 150 words or fewer.

This research, as part of a larger proposal presented by the Pacific School of Innovation and Inquiry (PSII) to the British Columbia Ministry of Education through the Innovation Grant program, seeks to aid PSII in building and deploying an interdisciplinary, competency-based assessment system for mathematical literacy that ties learning artifacts to competencies and contexts, allowing for integrated authentic assessment and reporting in a highly personalized learning environment.

5a. The research objective(s) and question(s)

- How can a competency based learning environment be adopted by a traditional education system?
- How can mathematical competence be demonstrated and assessed across multiple subject areas?
- Can mathematical literacy, as outlined in the revised BC curriculum, be detailed through systematic evidence, collected in a multi-disciplinary learning environment?
- Can an assessment tool be validly used to assess competency as identified in the revised BC curriculum?
- What role does computational thinking play in the development of competency in mathematical literacy?

5b. The importance and contributions of the research

The new structure of the revised British Columbia curriculum is moving away from objective oriented assessment and towards competency driven outcomes; however, currently there is no assessment structure that can validly and reliably measure these competencies. This research is of importance because it serves as one of the first attempts to create such a structure, focusing on the area of mathematical literacy which has been studied extensively across the globe.

5c. If applicable, provide background information or details that will enable the HREB to understand the context of the study when reviewing the application.

The Pacific School of Innovation and Inquiry is Victoria's newest high school (Grades 9 to 12), offering a truly personalized education. Through a formal inquiry process, learners at PSII develop interdisciplinary pathways that lead to projects and other learning activities to take them through a curriculum all their own, while also meeting or exceeding BC graduation requirements.

Jessica Asp is an educator at the Pacific School of Innovation and Inquiry, holding a Biochemistry degree from McGill University and a second degree in Education from the University of Victoria. Prior to joining the PSII team, Jessica's experiences in education have included teaching origami to elementary school students in Benin, West Africa, high school Science and English in Kenya, delivering workshops on the immune system to home learning students and supporting home learning families by distance education, teaching chemistry through continuing education to adult learners, coordinating science summer camps, as well as teaching a variety of science, math, and fibre arts classes at a small multi-aged alternative school. Jessica has been the main contact on this research project since she invited the researchers to take part in the project as part of the Innovation Grant program through the British Columbia Ministry of Education.

Neither the PI nor any other members of the research team have any additional role within the Pacific School of Innovation and Inquiry outside of this research project.

L. Recruitment

6. Recruitment and Selection of Participants

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- 6a. Briefly describe the target population(s) for recruitment. Ensure that all participant groups are identified (*e.g., group 1 - teachers, group 2 - administrators, group 3 - parents*).

Group 1 – Teachers

Group 2 – Students

- 6b. Why is each population or group of interest?

Group 1 – Teachers

This research project relies on the collection of both assessment documents, and learning artifacts from students, it will be necessary to recruit teachers to be active participants in this study.

Group 2 – Students

This research project relies on the collection of assessment documents, and learning artifacts from students, it will be necessary for students to be active participants in this study.

- 6c. What are the *salient* characteristics of the participants for your study? (*e.g., age, gender, race, ethnicity, class, position, etc.*)? List all inclusion and exclusion criteria you are using.

Group 1 – Teachers

Licensed British Columbia Teachers currently employed by PSII and involved in assessment of mathematics curriculum.

Group 2 – Students

British Columbia Secondary Students aged 14-18 currently enrolled in PSII.

- 6d. What is the desired number of participants for each group?

Group 1 – 5

Group 2 - 20

- 6e. Provide a detailed description of your recruitment process. Explain:

- i) List all source(s) for information used to contact potential participants (*e.g., personal contacts, listserves, publicly available contact information, etc.*). Clarify which sources will be used for which participant groups:

Teacher participants will be recruited by the Principal and Project Lead at PSII. All current students at PSII will be invited by the school to attend an information seminar on this research project.

- ii) List all methods of recruitment (*e.g., in-person, by telephone, letter, snowball sampling, word-of-mouth, advertisement, etc.*) If you will be using "snowball" sampling, clarify how this will proceed (*i.e., will participants be asked to pass on your study information to other potential participants?*). Clarify which methods will be used for which participant groups.

Students and teachers will attend an in-person information session at PSII.

- iii) If you will be using personal and/or private contact information to contact potential participants (as stated above), have the potential participants given permission for this, or will you use a neutral third party to

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assist you with recruitment? *Note that this is not a concern when public and/or business contact information is used.*

We will be using a neutral third party in the form of PSII Administration to obtain contact information for participants.

- iv) Who will recruit/contact participants (*e.g., researcher, assistant, third party, etc.*) Clarify this for each participant group.

Group 1 – Teachers

Researchers, in collaboration with PSII Administration, will identify teachers who are currently involved in assessment of mathematics at PSII and invite them to be involved in the information/recruitment session.

Group 2 – Students

PSII Administration will invite all current students to attend an information session at the school with their parents regarding this project. The invitation shall be distributed by email through the regular monthly parent newsletter to students and parents using the email addresses held on file by school administration.

- v) List and explain any relationship between the members of the research team (including third party recruiters or sponsors/clients of the research) and the participant(s) (*e.g., acquaintances, colleagues*). Complete item 7 if there is potential for a power relationship or a perceived power relationship (*e.g., instructor-student, manager-employee, etc.*). If you have a close relationship with potential participants (*e.g., family member, friend, close colleague, etc.*) clarify here the safeguards that you will put in place to mitigate any potential pressure to participate.

No relationships exist.

- vi) In chronological order (if possible) describe the steps in the recruitment process. (*Include how you will screen potential participants where applicable*). Consider where in the process permission of other bodies may be required.

Principal researchers will provide an initial information session to educators, at which they will obtain signatures from any teachers who will be participating in the study. Following this will be a second presentation to students and parents at the school. An information form will then be sent home to parents outlining what will be involved in the process and will be required from all students who will be participating.

7. Power Relationships (Dual-Role and Power-Over)

If you are completing this section, please refer to the: Guidelines For Ethics in Dual-Role Research for Teachers and Other Practitioners and the TCPS 2, Article 3.1 and Article 7.4.

Are you or any of your co-researchers in any way in a power relationship, including dual-roles, that could influence the voluntariness of a participant's consent? Could you or any of your co-researchers potentially be *perceived* to be in a power relationship by potential participants? *Examples of "power relationships" include teachers-students, therapists-clients, supervisors-employees and possibly researcher-relative or researcher-close friend where elements of trust or dependency could result in undue influence.*

Yes No Varies

If *yes* or *varies*, describe below:

- i) The nature of the relationship:
- ii) Why it is necessary to conduct research with participants over whom you have a power relationship:
- iii) What safeguards (steps) will be taken to ensure voluntariness and minimize undue influence, coercion or potential harm:

- iv) How will the power or dual-role relationship and associated safeguards be explained to potential participants:

Recruitment Materials Checklist:

Attach all documents referenced in this section (*check those that are appended*):

- Script(s) – in-person, telephone, 3rd party, e-mail, etc.
 Invitation to participate (*e.g., Psychology Research Participation System Posting*)
 Advertisement, poster, flyer
 None; please explain why (*e.g., consent form used as invitation/recruitment guide*)

Consent form will be used as invitation/recruitment guide

M. Data Collection Methods

8. Data Collection

Use the following sections in ways best suited to explain your project. If you have more than one participant group, be sure to explain which participant group(s) will be involved in which activity/activities or method(s).

8a. Which of the following methods will be used to collect data? *Check all that apply.*

| | |
|---|--|
| <input type="checkbox"/> Interviewing participants: <input type="checkbox"/> in-person <input type="checkbox"/> by telephone <input type="checkbox"/> using web-based technology (explain): <input type="checkbox"/> Conducting group interviews or discussions (including focus groups) | <input type="checkbox"/> Attach draft interview questions |
| <input type="checkbox"/> Administering a questionnaire or survey: <input type="checkbox"/> In person <input type="checkbox"/> by telephone <input type="checkbox"/> mail back <input type="checkbox"/> email <input type="checkbox"/> web-based* (see below) <input type="checkbox"/> Other, describe: *If using a web program with a server located in the United States (e.g., SurveyMonkey), or if there are other reasons that the data will be stored in the US (e.g., use of US-based cloud technology, sharing data with US colleagues, etc.), you must inform participants that their responses may be accessed via the U.S. Freedom Act. Please add the following to the consent form(s): <i>"Please be advised that this research study includes data storage in the U.S.A. As such, there is a possibility that information about you that is gathered for this research study may be accessed without your knowledge or consent by the U.S. government in compliance with the U.S. Freedom Act."</i> | <input type="checkbox"/> Attach questionnaire or survey: <input type="checkbox"/> standardized (one with established reliability and validity) <input type="checkbox"/> non-standardized (one that is un-tested, adapted or open-ended) |
| <input type="checkbox"/> Administering a computerized task (<i>describe in 8b or attach details</i>) | |
| <input type="checkbox"/> Observing participants <i>In 8b, describe who and what will be observed. Include where observations will take place. If applicable, forward an observational data collection sheet for review.</i> | |
| <input type="checkbox"/> Recording of participants and data using: | <input type="checkbox"/> Images used for analysis |

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| | | |
|--|--|--|
| <input type="checkbox"/> audio <input type="checkbox"/> note taking <input type="checkbox"/> data collection sheet (<i>attach</i>) | <input type="checkbox"/> video <input type="checkbox"/> flipcharts <input type="checkbox"/> other: | <input type="checkbox"/> photos or slides <input type="checkbox"/> Images used in disseminating results (<i>include release to use participant images in consent materials</i>) |
| <input type="checkbox"/> Using human samples (<i>e.g., saliva, urine, blood, hair</i>) <i>Attach your Biosafety Approval, or your correspondence with the <u>Biosafety Committee</u>, to this application. Note that Research Ethics Approval is contingent on Biosafety Approval.</i> | | |
| <input type="checkbox"/> Using specialized equipment/machines (<i>e.g., ultrasound, EEG, prototypes etc.</i>) or other. (<i>e.g., testing instruments that are not surveys or questionnaires</i>). Please specify: | | |
| <input type="checkbox"/> Using other testing equipment not captured under other categories. Please specify: | | |
| <input checked="" type="checkbox"/> Collecting materials supplied by, or produced by, the participants (<i>e.g., artifacts, paintings, drawings, photos, slides, art, journals, writings, etc.</i>) Please specify: | | |
| <input checked="" type="checkbox"/> Analyzing secondary data or secondary use of data (Refers to information/data that was originally gathered for a purpose other than the proposed research and is now being considered for use in research (<i>e.g., patient or school records, personal writings, lesson plans, etc.</i>)). <input type="checkbox"/> Secondary data involving anonymized information (Information/data is stripped of identifiers by another researcher or institution before being shared with the applicant). <input checked="" type="checkbox"/> Secondary data with identifying information (Data contains names and other information that can be linked to individuals, (<i>e.g., student report cards, employment records, meeting minutes, personal writings</i>)). <i>In item 8b describe the source of the data, who the appropriate data steward is, and explain whether (and how) consent was or will be obtained from the individuals for use of their data.</i> | | |
| <input type="checkbox"/> Other: Please specify: | | |

- 8b. Provide a sequential description of the procedures/methods to be used in your research study. Be sure to provide details for **all** methods checked in section 8a. Clarify which procedures/methods will be used for each participant group. Indicate which methods, if any, will be conducted in a group setting. *List all of the research instruments and interview/focus group questions, and append copies (if possible) or detailed descriptions of all instruments. If not yet finalized, provide drafts or sample items/questions.*

Phase 1 - Introduction (Ethics not required - no data collected)

- a) Competency assessment tool created (see attached) based on literature survey
- b) Competency assessment tool presented to PSII teachers
- c) Modified assessment tool piloted by PSII teachers

Phase 2 - Validation (Ethics Required)

- a) Materials will be collected, from instructors and students who have provided ethics approval, related to mathematical competency assessment.
 - i) Typical classroom work to be collected from students could include, but is not limited to quizzes, journal entries, self-reflections, concept maps, brainstorming charts, discussion questions and responses, completed worksheets, portfolio entries, written assignments, posters, pictures or visual representation of concepts, PowerPoint presentations, and websites. As PSII is a non-traditional learning environment, the concept of learning artifacts and classroom work may need to be expanded to include other pieces of evidence which demonstrate knowledge attainment.
 - i. Classroom work collected from students will be from regular academic exercises and limited to only those participants whom have agreed to take part in the study.

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- ii) Teacher assessment notes could include, but are not limited to, copies of the assessment form developed as part of this study, assessment notes included as part of the grading process of the above learning artifacts, responses to student reflections, responses to student portfolio entries, and notes regarding student growth outside of the context of learning artifacts.
- b) Validation of the model from this data
c) Presentation of Results
- 8c. Where will participation take place for each data collection method/procedure? *Provide specific location, (e.g., UVic classroom, private residence, participant's workplace). Clarify the locations for each participant group and/or each data collection method.*
- On-site at PSII**
- 8d. For each method, and in total, how much time will be required of participants? *Clarify this for each participant group, each data collection method, and any other research related activities.*
- No time is expected to be required of participants as the research involves a review of learning artifacts which are a regular part of the assessment practices currently in place at PSII.**
- 8e. Will participation take place during participants' office/work hours or instructional time?
- No Yes. Indicate whether permission is required (*e.g., from workplace supervisor, school principal, etc.*) and how this will be obtained:

Permission will be required from the Principal of PSII and will be obtained in writing prior to the commencement of this study.

Data Collection Methods Checklist:

Attach all documents referenced in this section (*check those that are appended. Where draft versions are appended please ensure that final versions are submitted when available. If final versions differ significantly after you have obtained Research Ethics approval, you will need to submit a Request for Modification:*

- Standardized Instrument(s)
 Survey(s), Questionnaire(s)
 Interview and/or Focus Group Questions
 Observation Protocols
 Other: **Typical Classroom Work and Teacher Assessment Notes**

N. Possible Benefits, Inconveniences, and Risks of Harm to Participants

9. Benefits

Identify any potential or known benefits associated with participation and explain below.
Keep in mind that the anticipated benefits should outweigh any potential risks.

- To the participant To society To the state of knowledge

The goal of this research is to develop more authentic assessment of mathematical literacy in high school students and aid the BC Ministry of Education in their application of the new Math Curriculum. This has far-reaching benefits which will not only influence individual student success but also could help to shift the Educational paradigm in British Columbia and beyond.

10. Inconveniences

Identify and describe any known or potential inconveniences to participants:
Consider all potential inconveniences, including total time devoted to the research.

Research may require limited time outside of instructional periods for teachers involved in the research.

11. Level of Risk

The TCPS 2 definition of "minimal risk research" is as follows:

"Research in which the probability and magnitude of possible harms implied by participation in the research is no greater than those encountered by the participant in those aspects of their everyday life that relate to the research."

Based on this definition, do you believe your research qualifies as "minimal risk research"?

Yes it is minimal risk. No, it is not minimal risk.

Explain your answer with reference to the risks of the study and the vulnerability of the participants:

Research will primarily involve collection and analysis of learning artifacts in much the same way as they might be used in the assessment of learning by another educator during a student's course of study.

12. Estimate of Risks of Harm

Consider the inherent foreseeable risks associated with your research protocol and complete the table below by putting an X in the appropriate boxes. Be sure to take into account the vulnerability of your target population(s) if applicable:

| Potential Risks of Harm | Very unlikely | Possibly | Likely |
|---|-------------------------------------|--------------------------|--------------------------|
| i) Emotional or psychological discomfort, such as feeling demeaned or embarrassed due to the research | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| ii) Fatigue or stress | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| iii) Social risks, such as stigmatization, loss of status, privacy and/or reputation | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| iv) Physical risks such as falls | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| v) Economic risk (e.g., job security, salary loss, etc.) | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| vi) Risk of incidental findings (<i>See Article 3.4 of the TCPS 2 for more information</i>) | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| vii) Other risks: | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

13. Possible Risks of Harm

If you indicated in Item 12 (i) to (vii) that any risks of harm are *possible* or *likely*, please explain below:

13a. What are the risks? (*i.e., elaborate on risks you have identified above*)

13b. What will you do to try to minimize, mitigate, or prevent the risks?

- 13c. How will you respond if the harm occurs? (*i.e., what is your plan?*)
- 13d. If you have indicated that there is a risk of Incidental Findings (vi) please outline your proposed protocol for information and/or action.
- 13e. If one or more of your participant groups could be considered vulnerable please describe any specific considerations you have built into the protocol to address this.

14. Risk to Researcher(s)

- 14a. Does this research study pose any risks to the researchers, assistants and data collectors?

No risks to researchers, assistants and data collectors

- 14b. If there are any risks, explain the nature of the risks, how they will be minimized, and how you will respond if they occur.

15. Deception

Will participants be fully informed of everything that will be required of them prior to the start of the research session?

- Yes No (*If no, complete the [Request to Use Deception](#) form on the ORS website*)

O. Incentives, Reimbursement and Compensation

- 16a. Is there any incentive, monetary or otherwise, being offered for participation in the research (*e.g., gifts, honorarium, course credits, etc.*)
- Yes No
- If yes, explain the nature of the incentive(s) and why you consider it necessary. *Also consider whether the amount or nature of the incentive could be considered a form of undue inducement or affect the voluntariness of consent. Clarify which participant groups will be provided with which incentives.*
- 16b. Is there any reimbursement or compensation for participating in the research (*e.g., for transportation, parking, childcare, etc.*)
- Yes No
- If yes, explain the nature of reimbursement or compensation and why you consider it necessary. *Also consider whether the amount of reimbursement or compensation could be considered a form of undue inducement or affect the voluntariness of consent. Clarify which participant groups will be provided with which kind of reimbursement or compensation.*
- 16c. Explain what will happen to the incentives, reimbursement or compensation if participants withdraw during data collection or any time thereafter (*e.g., compensation will be pro-rated, full compensation will be given, etc.*)

P. Free and Informed Consent

Consent encompasses a process that begins with initial contact and continues through to the end of the research process. Consult Article 3.2 of the TCPS 2 and Appendix V of the Guidelines for further information.

17. Participant's Capacity (Competence) to Provide Free and Informed Consent

Capacity refers to the ability of prospective or actual participants to understand relevant information presented about a research project, and to appreciate the potential consequences of their decision to participate or not participate. See the TCPS 2, Chapter 3, section C, for further information.

Identify your potential participants: (Check all that apply.)

| Competent | Non-Competent |
|--|---|
| <input checked="" type="checkbox"/> Competent adults <input type="checkbox"/> A protected or vulnerable population (e.g., inmates, patients) | <input type="checkbox"/> Non-competent adults: <input type="checkbox"/> Consent of family/authorized representative will be obtained <input type="checkbox"/> Assent of the participant will be obtained (note that assent of the participant is always required) |
| <input checked="" type="checkbox"/> Competent youth aged 13 to 18: <input checked="" type="checkbox"/> Consent of youth will be obtained and parental/guardian consent is required, due to institutional requirements (such as school districts) or due to the nature of the research (e.g., risks, etc.) <input type="checkbox"/> Consent of youth will be obtained, parents/guardians will be informed <input type="checkbox"/> Consent of youth will be obtained, parents/guardians will NOT be informed <input type="checkbox"/> Other, explain: | <input type="checkbox"/> Non-competent youth: <input type="checkbox"/> Consent of parent/guardian <input type="checkbox"/> Assent of the youth will be obtained (note that assent of the participant is always required) |
| <input type="checkbox"/> Competent children under 13 (who are able to provide fully informed consent): <input type="checkbox"/> Consent of child will be obtained and consent of parent/guardian will be obtained <input type="checkbox"/> Other, explain: | <input type="checkbox"/> Non-competent children (young children and/or children with limited abilities to provide fully informed consent): <input type="checkbox"/> Consent of parent/guardian <input type="checkbox"/> Assent of the child will be obtained (note that assent of the participant is always required) |

18. Means of Obtaining and Documenting Consent and/or Assent:

Check all that apply, consider all of your participant groups, attach copies of relevant materials, complete item 19:

- Signed consent** (Attach consent form(s) - see [template](#) available)
 Verbal consent (Attach verbal consent script(s) - see [template](#) available.)

Explain in 19 why written consent is not appropriate and how verbal consent will be documented.

- Letter of Information for **Implied** consent (e.g., anonymous, mail back or web-based survey. Attach information letter, see [template](#))
 Signed or Verbal assent for non-competent participants (Attach assent form(s), or verbal assent script(s)).

Explain how verbal assent will be documented in 19.

- Other means. Explain** in 19 and provide justification.

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- Consent will not be obtained. See TCPS 2 Articles 3.5 and 3.7. Explain in 19.
 Signed consent from the parents/guardians for youth/child participants (*Attach consent form(s)*).

Explain how parents/guardians will provide informed consent for child/youth participants in 19.

- Information letters for the parents/guardians of youth/child participants (*Attach information letter(s)*). If consent will not be obtained from parents/guardians and the parents/guardians will not be informed, explain why not in 19.

19. Informed Consent

Describe the exact steps (chronological order) that you will follow in the process of explaining, obtaining, and documenting informed consent. Ensure that consent procedures for all participant groups are identified (e.g., group 1 - teachers, group 2 – parents, group 3 – students). Be sure to indicate when participants will first be provided with the consent materials (e.g., prior to first meeting with the researcher?). If consent will not be obtained, explain why not with reference to the TCPS 2 Articles 3.5 and 3.7.

Researchers will provide an initial information session to PSII educators, which will outline the parameters of the study and review the consent form which all participants will be required to complete. Researchers will then provide each educator with a copy of the consent form to review and sign should they be willing to participate in the study.

Following this presentation to educators, a second presentation will be delivered to students and parents at the school. This presentation will outline the parameters of the study and review the consent form which all participants will be required to complete. Researchers will then provide each student and parent groups with a copy of the consent form to review and sign should they be willing to participate. Both the signature of the student and the parents will be required for them to participate in the study. Should students or parents require additional time to review the information, they will be free to take the form home and return to the researcher at their earliest convenience. An information form will then be sent home with students and parents outlining what will be involved in the process and will be required from all students who will be participating.

20. Ongoing Consent

Article 3.3 of the TCPS 2 states that consent shall be maintained throughout the research project. Complete this section if the research involves interacting with participants over multiple occasions (including review of transcripts, etc.), has multiple data collection activities, and/ or occurs over an extended period of time.

- 20a. Will your research occur over multiple occasions or an extended period of time (*including review of transcripts*)?

Yes No

- 20b. If yes, describe how you will obtain and document ongoing consent. If consent procedures differ for each group or activity, please clarify each group or activity that you are referring to.

Should research activities continue outside of the period identified in this application, or should further, or other, study procedures be added, a modification request shall be completed by the research team and a new consent form will be obtained from all participants involved in the study.

21. Participant's Right to Withdraw

Article 3.1 of the TCPS2 states that participants have the right to withdraw at any time and can withdraw their data and human biological materials.

Describe what participants will be told about their right to withdraw from the research at any time (*i.e., who to contact and how*). If compensation is involved, explain what participants will be told about compensation if they withdraw. *If you have different participant groups and/or different data collection methods, clarify the different procedures for withdrawing as necessary.*

The consent letter will outline that participants have the right to withdraw from the study at any time.

22. What will happen to a person's data if s/he withdraws part way through the study or after the data have been collected/submitted? If applicable, include information about visual data such as photos or videos.

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If you have different participant groups and/or different data collection methods, clarify the different procedures for withdrawing as necessary. Ensure this information is included in the consent documents.

- Participant will be asked if he/she agrees to the use of his/her data. Describe how this agreement will be documented:
- It will not be used in the analysis and will be destroyed.
- It is logistically impossible to remove individual participant data (e.g., anonymously submitted data).
- When linked to group data (e.g., focus group discussions), it will be used in summarized form with no identifying information.

Free and Informed Consent Checklist:

Attach all documents referenced in this section (check those that are appended):

- Consent and Assent Form(s) – Include forms for all participant groups and data gathering methods
- Letter(s) of Information for Implied Consent
- Verbal Consent and Assent Scripts

Q. Anonymity and Confidentiality

23. Anonymity

Anonymity means that no one, including the principal investigator, is able to associate responses or other data with individual participants.

23a. Will the participants be anonymous in the data gathering phase of research?

- Yes No

23b. Will the participants be anonymous in the dissemination of results (be sure to consider use of video, photos)?

- Yes
- Maybe. Explain below.
- No. If anonymity will not be protected and you plan to identify all participants with their data, provide the rationale below.

24. Confidentiality

Confidentiality means the protection of the person's identity (anonymity) and the protection, access, control and security of his or her data and personal information during the recruitment, data collection, reporting of findings, dissemination of data (if relevant) and after the study is completed (e.g., storage). The ethical duty of confidentiality refers to the obligation of an individual or organization to safeguard entrusted information. The ethical duty of confidentiality includes obligations to protect information from unauthorized access, use, disclosure, modification, loss or theft.

24a. Are there any limits to protecting the confidentiality of participants?

- No, confidentiality of participants and their data will be completely protected
- Yes, there are some limits to the researcher's ability to protect the confidentiality of participants (Check relevant boxes below.)
- Limits due to the nature of group activities (e.g., focus groups): The researcher cannot guarantee confidentiality
- Limits due to context: The nature or size of the sample from which participants are drawn makes it possible to identify individual participants (e.g., school principals in a small town, position within an organization)

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- Limits due to selection: The procedures for recruiting or selecting participants may compromise the confidentiality of participants (*e.g., participants are identified or referred to the study by a person outside the research team*)
- Limits due to legal requirements for reporting (*e.g., legal or professional*)
- Limits due to local legislation such as the U.S.A. Freedom Act (*e.g., when there will be data storage in the United States*). When using USA based data instruments and data storage systems researchers are responsible for determining if this applies.
- Other:

- 24b. If confidentiality will be protected, describe the procedures to be used to ensure the anonymity of participants and for preserving the confidentiality of their data (*e.g., pseudonyms, changing identifying information and features, coding sheet, etc.*) *If you will use different procedures for different participant groups and/or different data methods be sure to clarify each procedure.*

Researchers will work with the educational institution to create a coding sheet that will remove identifiable information from data collected from each of the participants in the study.

- 24c. If there are limits to confidentiality indicated in section 24a. above, explain what the limits are and how you will address them with the participants. *If there are different procedures for different participant groups and/or different data collection methods, be sure to clarify each procedure.*

R. Use and Disposal of Data

25. Use(s) of Data

- 25a. What use(s) will be made of all types of data collected (*field notes, photos, videos, audiotapes, transcripts, etc.*)?

All hard copy resources will be digitized for further analysis.

- 25b. Will your research data be analyzed, now or in future, by yourself for purposes other than this research project?

Yes No Possibly

- 25c. If yes or possibly, indicate what purposes you plan for this data and how will you obtain consent for future data analysis from the participants (*e.g., request future use in current consent form*)?

- 25d. Will your research data be analyzed, now or in future, by other persons for purposes other than explained in this application?

Yes No Possibly

- 25e. If yes or possibly:

- i) Indicate whether the data will contain identifiers when it is provided to the other researchers or whether it will be fully anonymous (*note that "fully anonymous" means that there is no identifying information, links, keys, or codes that allow the data to be re-identified*).
- ii) How will you obtain consent from the participants for future data analysis by other researchers? (*If the data will be transferred in fully anonymous form, this request for future use can be made in the current consent*

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form. If the data will contain identifiers or links/keys/codes for re-identification, consider requesting permission to contact the participants in the future, to obtain consent for the use of the data at that time).

26. Commercial Purposes

26a. Do you anticipate that this research will be used for a commercial purpose?

Yes No

26b. If yes, explain how the data will be used for a commercial purpose:

26c. If yes, indicate if and how participants will benefit from commercialization.

27. Maintenance and Disposal of Data

Describe your plans for protecting data during the project, and for preserving, archiving, or destroying all the types of data associated with the research (e.g., paper records, audio or visual recordings, electronic recordings, coded data) after the research is completed:

27a. means of storing and securing data (e.g., encryption, password protected computer files, locked cabinet, separation of key codes from raw data etc.):

All digital files will be password protected and be stored on a portable hard disk drive which will be locked in a filing cabinet, in a locked room, when not in use. Key codes will be stored on a separate flash drive and locked in a separate location in the room. Hard copy files will similarly be stored in a locked filing cabinet in a locked room when not in use.

27b. location of storing data (include location of data-storage servers if using web-based technology):

All digital files will be stored on a portable hard disk drive or a flash drive.

27c. duration of data storage (if data will be kept indefinitely, explain why this is necessary and state whether the data will contain identifiers or links to identifiers):

Data will be stored for a period of 12 months, should there be a necessity to re-examine the results.

27d. methods of destroying or archiving data. If archiving data, please describe measures to secure or protect the data. If the archiving will involve a third party (e.g., library, community agency, Aboriginal band, etc.) please provide details:

Digital files will be deleted, and the disk drives formatted on the completion of the project. Hard copy files will be returned to the institution or will be confidentially shredded utilizing services provided through the University.

28. Dissemination

How do you anticipate disseminating the research results? (Check all that apply)

- Thesis/Dissertation/Class presentation
- Presentations at scholarly meetings Published article, chapter or book
- Internet (Students: Most UVic Theses are posted on "UVicSpace" and can be accessed by the public)

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- Media (*e.g., newspaper, radio, TV*)
- Directly to participants and/or groups involved. Indicate how: (*e.g., report, executive summary, newsletter, information session*):
- Other, explain:

S. Conflict of Interest

29a. Apart from a declared dual-role relationship (Section K, item 7), are you or any of the research team members in a perceived, actual or potential conflict of interest regarding this research project (*e.g., partners in research, private interests in companies or other entities*)?

- Yes No

29b. If yes, please provide details of the conflict and how you propose to manage it:

Attachments*

*Ensure that all applicable attachments are included with all copies of your application. Incomplete applications will not be entered into the review system. You will be notified in this case.

Information for Submission

- Applications may be printed and submitted double-sided
- Do **not** staple the original application with original signatures (clips O.K.)
- The two photocopies may be individually stapled or clipped
- Do **not** staple or clip the individual appendices

Title and label attachments as Appendix 1, 2, 3 etc. and attach the following documents (check those that are appended):

Section I - Recruitment Materials:

- Script(s) – in-person, telephone, 3rd party, e-mail, etc.
- Invitation to participate
- Advertisement, Poster, Flyer

Section J - Data Collection Methods:

- Standardized Instrument(s)
- Survey(s), Questionnaire(s)
- Interview and/or Focus Group Questions
- Observation Protocols
- Other:

Section M - Free and Informed Consent:

- Consent Form(s) – Include forms for all participant groups and data gathering methods
- Assent Form(s)
- Letter(s) of Information for Implied Consent
- Verbal Consent Script

- Approval from external organizations (or proof of having made a request for permission)
- Permission to gain access to confidential documents or materials
- Request to Use Deception form
- Biosafety Committee Approval
- Other, please describe:

APPENDIX 1:
Standardized Instrument

Learning Artifact Competency Assessment

| | | | | | | | | | | | |
|--|--------------------|---------------------|-----------|------------------|------------|-----------|--|-----------|--------|------------|------------|
| Learner Name: | | Assessor Name: | | | | | | | | | |
| Date of Artifact Creation: | | Date of Assessment: | | | | | | | | | |
| Description of Artifact: | | | | | | | | | | | |
| Mathematical Competency Area | Formulating | | | Employing | | | Interpreting, Applying and Evaluating | | | | |
| | Beginning | Developing | Expanding | Fluent | Proficient | Beginning | Developing | Expanding | Fluent | Proficient | |
| Communicating | Assessment | | | | | | | | | | Assessment |
| | Comments | | | | | | | | | | Comments |
| Mathematizing | Assessment | | | | | | | | | | Assessment |
| | Comments | | | | | | | | | | Comments |
| Representation | Assessment | | | | | | | | | | Assessment |
| | Comments | | | | | | | | | | Comments |
| Reasoning and argument | Assessment | | | | | | | | | | Assessment |
| | Comments | | | | | | | | | | Comments |
| Devising strategies for solving problems | Assessment | | | | | | | | | | Assessment |
| | Comments | | | | | | | | | | Comments |
| Using symbolic, formal and technical language and operations | Assessment | | | | | | | | | | Assessment |
| | Comments | | | | | | | | | | Comments |
| Using mathematical tools | Assessment | | | | | | | | | | Assessment |
| | Comments | | | | | | | | | | Comments |

Mathematical Competency Assessment Rubric

| | Formulating situations mathematically | Employing mathematical concepts, facts, procedures and reasoning | Interpreting, applying and evaluating mathematical outcomes |
|---|--|---|---|
| Communicating | Read, decode, and make sense of statements, questions, tasks, objects or images, in order to form a mental model of the situation | Articulate a solution, show the work involved in reaching a solution and/or summarise and present intermediate mathematical results | Construct and communicate explanations and arguments in the context of the problem |
| Mathematising | Identify the underlying mathematical variables and structures in the real world problem, and make assumptions so that they can be used | Use an understanding of the context to guide or expedite the mathematical solving process, e.g. working to a context-appropriate level of accuracy | Understand the extent and limits of a mathematical solution that are a consequence of the mathematical model employed |
| Representation | Create a mathematical representation of real-world information | Make sense of, relate and use a variety of representations when interacting with a problem | Interpret mathematical outcomes in a variety of formats in relation to a situation or use, compare or evaluate two or more representations in relation to a situation |
| Reasoning and Argument | Explain, defend or provide a justification for the identified or devised representation of a real-world situation | Explain, defend or provide a justification for the processes and procedures used to determine a mathematical result or solution Connect pieces of information to arrive at a mathematical solution, make generalisations or create a multi-step argument | Reflect on mathematical solutions and create explanations and arguments that support, refute or qualify a mathematical solution to a contextualised problem |
| Devising Strategies for solving problems | Select or devise a plan or strategy to mathematically reframe contextualised problems | Activate effective and sustained control mechanisms across a multi-step procedure leading to a mathematical solution, conclusion or generalisation | Devise and implement a strategy in order to interpret, evaluate and validate a mathematical solution to a contextualised problem |
| Using symbolic, formal and technical language | Use appropriate variables, symbols, diagrams and standard models in order to represent a real-world problem using symbolic/formal language | Understand and utilise formal constructs based on definitions, rules and formal systems as well as employing algorithms | Understand the relationship between the context of the problem and representation of the mathematical solution. Use this understanding to help interpret the solution in context and gauge the feasibility and possible limitations of the solution |
| Using mathematical tools | Use mathematical tools in order to recognise mathematical structures or to portray mathematical relationships | Know about and be able to make appropriate use of various tools that may assist in implementing processes and procedures for determining mathematical solutions | Use mathematical tools to ascertain the reasonableness of a mathematical solution and any limits and constraints on that solution, given the context of the problem |

REVISED

JAN 29 2018

APPENDIX 2



**University
of Victoria**

Participant Consent Form - Student

Mathematical Competency Assessment in Secondary Education

You/your child are invited to participate in a study entitled Mathematical Competency Assessment in Secondary Education that is being conducted by Andrew MacLean.

Andrew MacLean is a Graduate Student in the department of Curriculum and Instruction at the University of Victoria and you may contact him if you have further questions by email at

As a Graduate student, Andrew is required to conduct research as part of the requirements for a degree in Education. This research is being conducted under the supervision of Dr. Ulrike Stege and Dr. Todd Milford. You may contact them at _____ respectively.

Purpose and Objectives

The purpose of this research project, as part of a larger proposal presented by the Pacific School of Innovation and Inquiry (PSII) to the British Columbia Ministry of Education through the Innovation Grant program, is to aid PSII in ~~building and deploying~~ creating an interdisciplinary, competency-based assessment system for mathematical literacy that ~~ties learning artifacts to competencies and contexts, allowing~~ allows for ~~integrated~~ authentic assessment and reporting in a highly personalized learning environment..

Importance of this Research

Research of this type is important because the new structure of the revised British Columbia curriculum is moving away from ~~objective oriented traditional assessment outcomes, such as test results,~~ and towards competency driven outcomes; however, currently there is no assessment structure that can ~~validly and~~ reliably measure these competencies. This research ~~is of importance because it serves as~~ represents one of the first attempts to create such a structure, focusing on the area of mathematical literacy which has been studied extensively across the globe.

Participants Selection

You/your child are being asked to participate in this study because this research relies primarily on the collection of assessment documents, and learning artifacts (outlined below), from students. Therefore, it will be necessary for students to be active participants in this study.

What is involved

If you consent to you/your child voluntarily participating in this research, that participation will include collection of assessment documents, and learning artifacts, created as part of regular academic exercises during the study which will be ~~analyzed~~ examined in relation to mathematical competency ~~assessment~~. Typical classroom work to be collected could include, but is not limited to quizzes, journal entries, self-reflections, concept maps, brainstorming charts, discussion questions and responses, completed worksheets, portfolio entries, written assignments, posters, pictures or visual representation of concepts, PowerPoint presentations, and websites. As PSII is a non-traditional learning environment, the concept of learning artifacts and classroom work may need to be expanded to include other pieces of evidence which demonstrate knowledge attainment.

This classroom work will be from regular academic exercises and limited to only those participants whom have agreed to take part in the study.

Risks

There are no known or anticipated risks to you/your child by participating in this research.

Benefits

The potential benefits of you/your child's participation in this research includes the development of more authentic assessment of mathematical literacy in high school students which can aid the BC Ministry of Education in their application of the new Math Curriculum. This has far-reaching benefits which will not only influence individual student success but also could help to shift the Educational paradigm in British Columbia and beyond.

Voluntary Participation

You/your child's participation in this research is, and must be, completely voluntary and you are under no obligation to participate in the study. If you/your child do decide to participate, you/your child may withdraw at any time without any consequences or any explanation. If you/your child do withdraw from the study, your data will not be used in the analysis and the data will be destroyed. Participation in this project will not affect academic standing, relationships or grades in any way, whether individuals choose to participate or not.

On-going Consent

To make sure that you continue to consent to your/your child's participation in this research, I will provide another consent form if the research activities continue outside of the period identified for the study.

Anonymity

In terms of protecting your anonymity, while student information will be known by researchers during the collection and analysis of the learning artifacts, no identifiable information will be shared in the final, distributed results.

Confidentiality

Your confidentiality and the confidentiality of the data will be protected through multiple methods. Firstly, researchers will work with administration to create a coding sheet which will remove identifiable information from data collected. All hard copy data will also be digitized, with physical copies stored in a locked filing cabinet and all digital files stored on an encrypted hard drive. Coding information will be stored on a separate flash drive and kept in a separate locked location away from the data collected.

Dissemination of Results

It is anticipated that the results of this study will be shared with others through published articles, scholarly presentations, and through a thesis and associated presentations and digital distribution. Should a thesis be developed as a result of this study, it will be available on the Internet via "UVicSpace". Results will also be shared with members of the PSII administration, all study participants and the student body of PSII.

Disposal of Data

Data from this study, in the form of physical copies, will be disposed of either by way of shredding, or return to PSII administration, with all digital data on hard disks being erased and formatted at the completion of the study.

Contacts

For individuals that may be contacted regarding this study please refer to the information at the beginning of the consent form.

In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or ethics@uvic.ca).

Your signature below indicates that you understand the above conditions of participation in this study, that you have had the opportunity to have your questions answered by the researchers, and that you consent to your/your child's participation in this research project.

Name of Participant (Student) *Signature* *Date*

Name of Parent/Guardian *Signature* *Date*

A copy of this consent will be left with you, and a copy will be taken by the researcher.

APPENDIX 3

REVISED
JAN 29 2018
**University
of Victoria**
Participant Consent Form - Teacher
Mathematical Competency Assessment in Secondary Education

You are invited to participate in a study entitled Mathematical Competency Assessment in Secondary Education that is being conducted by Andrew MacLean.

Andrew MacLean is a Graduate Student in the department of Curriculum and Instruction at the University of Victoria and you may contact him if you have further questions by email at

As a Graduate student, Andrew is required to conduct research as part of the requirements for a degree in Education. This research is being conducted under the supervision of Dr. Ulrike Stege and Dr. Todd Milford. You may contact them at _____ respectively.

Purpose and Objectives

The purpose of this research project, as part of a larger proposal presented by the Pacific School of Innovation and Inquiry (PSII) to the British Columbia Ministry of Education through the Innovation Grant program, is to aid PSII in building and deploying an interdisciplinary, competency-based assessment system for mathematical literacy that ties learning artifacts to competencies and contexts, allowing for integrated authentic assessment and reporting in a highly personalized learning environment.

Importance of this Research

Research of this type is important because the new structure of the revised British Columbia curriculum is moving away from objective oriented assessment and towards competency driven outcomes; however, currently there is no assessment structure that can validly and reliably measure these competencies. This research is of importance because it serves as one of the first attempts to create such a structure, focusing on the area of mathematical literacy which has been studied extensively across the globe.

Participants Selection

You are being asked to participate in this study because this research relies primarily on the collection of assessment documents, and learning artifacts, completed by teachers for students in relation to mathematics assessment. Therefore, it will be necessary for teachers to be active participants in this study.

What is involved

If you consent to voluntarily participating in this research, that participation will include collection of assessment documents, and learning artifacts, created as part of regular academic exercises by you for your students during the study, which will be analyzed in relation to mathematical competency assessment. Teacher assessment notes could include, but are not limited to, copies of the assessment form developed as part of this study, assessment notes included as part of the grading process of regularly learning artifacts, responses to student reflections, responses to student portfolio entries, and notes regarding student growth outside of the context of learning artifacts.

Risks

There are no known or anticipated risks to you by participating in this research.

Benefits

The potential benefits of your participation in this research includes the development of more authentic assessment of mathematical literacy in high school students which can aid the BC Ministry of Education in their application of the new Math Curriculum. This has far-reaching benefits which will not only influence individual student success but also could help to shift the Educational paradigm in British Columbia and beyond.

Voluntary Participation

Your participation in this research is, and must be, completely voluntary and you are under no obligation to participate in the study. If you do decide to participate, you may withdraw at any time without any consequences or any explanation. If you do withdraw from the study your data will not be used in the analysis and the data will be destroyed. Participation in this project will not affect workplace relationships or employment in any way, whether individuals choose to participate or not.

On-going Consent

To make sure that you continue to consent to your participation in this research, I will provide another consent form if the research activities continue outside of the period identified for the study.

Anonymity

In terms of protecting your anonymity, while student and teacher information will be known by researchers during the collection and analysis of the learning artifacts, no identifiable information will be shared in the final, distributed results.

Confidentiality

Your confidentiality and the confidentiality of the data will be protected through multiple methods. Firstly, researchers will work with administration to create a coding sheet which will remove identifiable information from data collected. All hard copy data will also be digitized, with physical copies stored in a locked filing cabinet and all digital files stored on an encrypted hard drive. Coding information will be stored on a separate flash drive and kept in a separate locked location away from the data collected.

Dissemination of Results

It is anticipated that the results of this study will be shared with others through published articles, scholarly presentations, and through a thesis and associated presentations and digital distribution. Should a thesis be developed as a result of this study, it will be available on the Internet via "UVicSpace". Results will also be shared with members of the PSII administration, all study participants and the student body of PSII.

Disposal of Data

Data from this study, in the form of physical copies, will be disposed of either by way of shredding, or return to PSII administration, with all digital data on hard disks being erased and formatted at the completion of the study.

Contacts

For individuals that may be contacted regarding this study please refer to the information at the beginning of the consent form.

In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or ethics@uvic.ca).

Your signature below indicates that you understand the above conditions of participation in this study, that you have had the opportunity to have your questions answered by the researchers, and that you consent to your/your child's participation in this research project.

Name of Participant

Signature

Date

A copy of this consent will be left with you, and a copy will be taken by the researcher.

APPENDIX 4

Script for Invitation to PSII Teachers

Fellow PSII Educator,

As you are all aware, over the past few years the Pacific School of Innovation and Inquiry has been involved in the BC Ministry of Education's K-12 Innovation Partnership program, with the goal of building and deploying an interdisciplinary, competency based digital portfolio system that ties learning artifacts to competencies and contexts. As part of this partnership, we have invited researchers from various institutions to observe some of the work we are doing at PSII and perform focussed study on specific components of our programming.

We would like to invite you to attend an information on one such study entitled "Mathematical Competency Assessment in Secondary Education" that is being conducted by Andrew MacLean, a Graduate Student in the department of Curriculum and Instruction at the University of Victoria. This study aims to develop an assessment structure that can validly and reliably measure mathematical competency in an interdisciplinary environment, through analysis of learning and assessment artifacts created by PSII students and educators.

Participation in the information session, and the related study, are completely voluntary and you are under no obligation to participate in any way. Professional relationships and employment status will not be affected in any way, whether you choose to participate or not.

Should you have any questions prior to the information session, please feel free to contact us directly and we will be happy to provide any information you require.

Sincerely,

PSII Administration

Script for Invitation to PSII Parents/Guardians

Dear Parents/Guardians of PSII Students,

As some of you may know, over the past few years the Pacific School of Innovation and Inquiry has been involved in the BC Ministry of Education's K-12 Innovation Partnership program, with the goal of building and deploying an interdisciplinary, competency based digital portfolio system that ties learning artifacts to competencies and contexts. As part of this partnership, we have invited researchers from various institutions to observe some of the work we are doing at PSII and perform focussed study on specific components of our programming.

We would like to invite you and your students to attend an information on one such study entitled "Mathematical Competency Assessment in Secondary Education" that is being conducted by Andrew MacLean, a Graduate Student in the department of Curriculum and Instruction at the University of Victoria. This study aims to develop an assessment structure that can validly and reliably measure mathematical competency in an interdisciplinary environment, through analysis of learning and assessment artifacts created by PSII students and educators.

Participation in the information session, and the related study, are completely voluntary and students are under no obligation to participate in any way. Academic standing, relationships, and/or grades will not be affected in any way, whether individuals choose to participate or not.

Should you have any questions prior to the information session, please feel free to contact us directly and we will be happy to provide any information you require.

Sincerely,

PSII Administration

APPENDIX 5

Pacific School of Innovation and Inquiry

100 – 808 Douglas St. Victoria BC V8W 2B6

www.learningstorm.org



To Whom It May Concern,

The Pacific School of Innovation and Inquiry supports the project “Mathematical Competency Assessment in Secondary Education” and has approved the research portion to take place on-site at the school located at 100-808 Douglas Street during the time period of February 1, 2018 until March 31, 2018.

Furthermore, with regards to the Ethic Board Research Approval Application submitted for this project, we affirm that:

- We have read this application.
- The research will be conducted in accordance with the University of Victoria regulations, policies and procedures governing the ethical conduct of research involving human participants and all relevant sections of the TCPS 2.
- The conduct of the research will not commence until ethics approval has been granted.
- The researcher(s) will seek further HREB review if the research protocol is modified.
- Adequate supervision will be provided for students and/or staff.
- That adequate research infrastructure is available for the conduct and completion of this research.

If you have any questions, please do not hesitate to contact us.

Sincerely,

Jessica Asp

Educator
Pacific School of Innovation and Inquiry

CREATING A COMPETENCY CONTINUUM

Assessing Competency in Mathematical Literacy

PSII Core Competencies

| Competency | Description |
|---|---|
| Ecological literacy | The understanding of closed systems, including the relationships of elements or organisms with one another and with their context or physical surroundings. |
| Reading, writing, speaking, and listening | The application of skills and techniques involved in effective communication in K-12's world. |
| Mathematical literacy | Knowledge of the language of math, including what numbers and other symbols mean, how space (both real and imaginary) can be explored and described through math, and mean, how space (both real and imaginary) can be explored and described through math, and choosing mathematical strategies to solve problems effectively. |
| Collaboration and leadership | The application of skills, attitudes, and techniques involved in interpersonal communication, including analysis, understanding, evaluation, and problem- and solution-finding. |

Current Competency Assessment Tool

MM YYYY - Progress Report

Name: X

| Competency | Comments |
|---|----------|
| Ecological literacy | |
| Reading, writing, speaking, and listening | |
| Mathematical literacy | |
| Collaboration and leadership | |
| Critical and creative thinking | |
| Cultural awareness and understanding | |
| Media and information literacy | |
| Personal planning and responsibility | |

Current Curriculum Assessment Tool

| Course | Approximate % of course completed | Final Course Mark | Average depth at which course outcomes are being assessed | Additional Comments |
|--|-----------------------------------|-------------------|---|---------------------|
| Foundations of Mathematics and Pre-calculus 10 | | | | |
| Science 9 | | | | |
| Science 10 | | | | |
| English 10 | | | | |

Assessment Using Fuzzy Logic

- ◆ Evaluating learning outcomes in PBL using fuzzy logic techniques
- ◆ Fuzzy Logic as a Tool for Assessing Students' Knowledge and Skills
- ◆ Using Fuzzy Logic in Educational Measurement: The Case of Portfolio Assessment

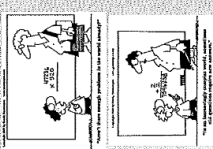
Figure 1: Semantic ambiguities between levels of competence

| Criteria | Scale | | | | | | | | | | |
|----------|-------|---|---|---|---|---|---|---|---|---|----|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |

Figure 6 Fuzzy rating ascribed to each section of portfolio for the 'Authenticity' quality

Assessing Mathematical Competency

- ◆ Programme for International Student Assessment (PISA) 2015 Proposed Framework
- ◆ Danish Competencies and the Learning of Mathematics (KOM) Project



9

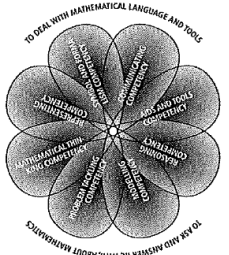


Figure 1. A visual representation of the eight mathematical competencies presented and exemplified in the KOM report (Niis & Højgaard, 2011, p. 45).

10

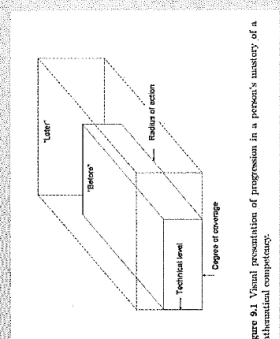


Figure 9.1. Visual representation of progression in a person's mastery of a mathematical competency.

11

PISA 2015 Mathematical Literacy Framework

| | Formulating situations mathematically | Employing mathematical concepts, facts, procedures and reasoning | Interpreting applying and evaluating mathematical outcomes |
|---------------|--|---|---|
| Communicating | Read, decode, and make sense of statements, questions, tasks, and problems to form a mental model of the situation | Articulate a solution, show the work involved in reaching a solution, and present intermediate mathematical results | Construct and communicate explanations and arguments in the context of the problem |
| Mathematizing | Identify the underlying mathematical variables and structures in the real world so that they can be used | Use an understanding of the mathematical solving process, mathematical models employed, and appropriate level of accuracy | Understand the extent and limits of a mathematical solution that are a consequence of the mathematical model employed |

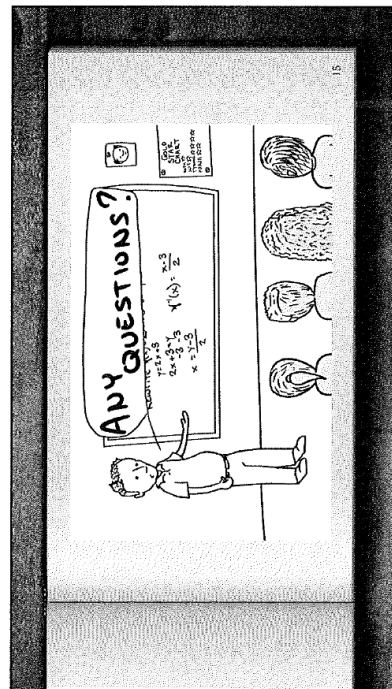
12

Learning Artifact Assessment

| Description of Artifact | Formulating | | | | | | | | | | Employing | | | | | | | | | | | |
|-----------------------------------|-------------|---------|-----------|-------|----------|---------|-------------|-------------|----------|-------|-----------|---------|-----------|-------|----------|---------|-------------|-------------|----------|-------|---|----|
| | Identify | Examine | Interpret | Apply | Transfer | Reflect | Communicate | Collaborate | Transfer | Apply | Identify | Examine | Interpret | Apply | Transfer | Reflect | Communicate | Collaborate | Transfer | Apply | | |
| Mathematical Competency Area | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Assessment Comments | | | | | | | | | | | | | | | | | | | | | | |
| Communicating Assessment Comments | | | | | | | | | | | | | | | | | | | | | | |
| Mathematising Assessment Comments | | | | | | | | | | | | | | | | | | | | | | |

Proposed Competency Continuum

| Competency | Depth at which competencies are being met | | | | | Additional Comments |
|--------------------------------|---|---|---|---|---|---------------------|
| | B | D | E | F | P | |
| Ecological literacy | | | | | | |
| Mathematical literacy | | | | | | |
| Collaboration and leadership | | | | | | |
| Critical and creative thinking | | | | | | |






Office of Research Services | Human Research Ethics Board
 Michael Williams Building Rm B202 PO Box 1700 STN CSC Victoria BC V8W 2Y2 Canada
 250-472-4545 | 250-721-8960 | uvic.ca/research | ethics@uvic.ca

Modification of an Approved Protocol

| | |
|---|--|
| PRINCIPAL INVESTIGATOR: Andrew MacLean | ETHICS PROTOCOL NUMBER: 17-484 Minimal Risk Review - Delegated |
| UVic STATUS: Master's Student | ORIGINAL APPROVAL DATE: 31-Jan-18 |
| UVic DEPARTMENT: EDCI | MODIFIED ON: 19-Apr-18 |
| SUPERVISOR: Dr. Todd Milford | APPROVAL EXPIRY DATE: 30-Jan-19 |
| PROJECT TITLE Mathematical Competency Assessment in Secondary Education | |
| RESEARCH TEAM MEMBERS Co-Investigators: Todd Milford (UVic), Ulrike Stege (UVic); School Lead: Jessica Asp (Pacific School of Innovation & Inquiry) | |
| DECLARED PROJECT FUNDING: None | |
| CONDITIONS OF APPROVAL | |
| This Certificate of Approval is valid for the above term provided there is no change in the protocol. | |
| Modifications 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. | |
| Renewals 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. | |
| Project Closures 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. | |
| Certification | |
| 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. | |
| <hr/> Dr. Rachael Scarth Associate Vice-President Research Operations | |

Certificate Issued On: 19-Apr-18

17-484
Maclean, Andrew





**University
of Victoria**

**Human Research Ethics
Request for Modification of an Approved Protocol**

The Request for Modification form is an institutional protocol based on the
[Tri-Council Policy Statement on the Ethical Conduct for Research Involving Humans](#)

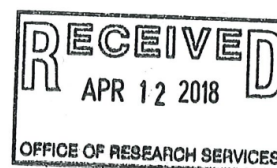
Instructions:

1. Download this Request for Modification and complete it on your computer. Hand written applications will not be accepted.
2. **Submit two (2) copies of this completed application with all attachments - one (1) copy must have original signatures - and send to:**
Human Research Ethics, Michael Williams Building (MWB), Room B202, University of Victoria, PO Box 1700 STN CSC, Victoria BC V8W 2Y2 Canada. The review period for Modifications is approximately two weeks.
3. If you need assistance, contact the Human Research Ethics Office at (250) 472-4545 or ethics@uvic.ca
4. Please note that applications are screened and will not be entered into the review system if incomplete (e.g., missing required attachments, signatures, documents). You will be notified in this case.
5. In cases where the nature and/or the extent of the proposed modifications are substantial such that the changes result in a study that deviates substantially from the originally approved study or previous modified study, the research ethics board reserves the right to require that a new application form be submitted.

A. Principal Investigator

If there is more than one Principal Investigator, provide their name(s) and contact information below in Section B, Other Investigator(s) & Research Team.

Last Name: **MacLean** First Name: **Andrew**
 Department/Faculty: **Curriculum & Instruction** UVic Email:
 Phone: Primary Email :
 Mailing Address (if different from Department/Faculty) including postal code:



Title/Position: (Must have a UVic appointment or be a registered UVic student)

- Faculty Undergraduate Ph.D. Student
 Staff Master's Student Post-Doctoral
 Adjunct or Sessional Faculty (Appointment start and end dates): _____

Students: Provide your Supervisor's information:

Name: **Dr. Todd Milford** Email:
 Department/Faculty: **Curriculum & Instruction** Phone:
 Graduate Students: Provide your Graduate Secretary's email address: **edcigrad@uvic.ca**

All PIs: Provide any additional contacts for email correspondence:

Name: | Email: |
 Name: | Email: |

| | | |
|--|-----------------------|----------------------|
| FOR THE HUMAN RESEARCH ETHICS OFFICE USE ONLY | | Current Protocol No. |
| Board Chair Approval Signature: | | Approval Date: |
| Original Start Date: | Approval Expiry Date: | Renewal Due: |

B. Project InformationOriginal or most recent Protocol Number: **17-484**Original Project Title: **Mathematical Competency Assessment in Secondary Education**Project Title if modified: **Mathematical Competency Assessment in Secondary Education**Date Recruitment or Data Collection began: **1 February 2018**Anticipated End Date of Data Collection: **30 May 2018**Is this project connected/associated/linked to one that has been recently submitted? Yes No

If yes, provide further information:

All Current Investigator(s) and Research Team:

(Include all current and new co-investigators, students, employees, volunteers, community organizations.)

| Contact Name | Role in Research Project | Institutional Affiliation | Email or Phone |
|--------------|--------------------------|--|----------------|
| Todd Milford | Co-Investigator | University of Victoria | |
| Ulrike Stege | Co-Investigator | University of Victoria | |
| Jessica Asp | School Lead | Pacific School of Innovation & Inquiry | |

For Faculty Only: Any Graduate Student Research Assistants who will use the data to fulfill UVic thesis/ dissertation/ academic requirements: Include all current Graduate Student Research Assistants

Student/Research Assistant _____ Email or Phone _____

C. Agreement and Signatures**Principal Investigator and Student Supervisor affirm that:**

- *I have read this modification and it is complete and accurate.*
- *The research will be conducted in accordance with the University of Victoria regulations, policies and procedures governing the ethical conduct of research involving human participants and all relevant sections of the TCPS 2.*
- *The conduct of the modified protocol will not commence until ethics approval has been granted.*
- *The researcher(s) will seek further HREB review if the research protocol is further modified.*
- *Adequate supervision will be provided for students and/or staff.*

Principal Investigator**Student's Supervisor**

Signature _____

Signature _____

Print Name _____

Print Name _____

Date _____

Date _____

Departmental Chair, Director or Dean

I affirm that adequate research infrastructure is available for the conduct and completion of this research.

Signature

Print Name

Date

D. Project Funding

Have there been any changes to the funding of this project since the previous ethics approval (annual renewal or modification)? No Yes

If yes, please complete the following:

| Source of Project Funding | Year Applied | Status | Project Title Used in Funding Application (or additional information) |
|---------------------------|--------------|---|---|
| | | <input type="checkbox"/> New - Pending <input type="checkbox"/> New - Approved <input type="checkbox"/> Completed | |
| | | <input type="checkbox"/> New - Pending <input type="checkbox"/> New - Approved <input type="checkbox"/> Completed | |
| | | <input type="checkbox"/> New - Pending <input type="checkbox"/> New - Approved <input type="checkbox"/> Completed | |
| | | <input type="checkbox"/> New - Pending <input type="checkbox"/> New - Approved <input type="checkbox"/> Completed | |

If you have applied for new funding since the previous ethics approval (annual renewal or modification), have you submitted a funding application or contract notification to the UVic Office of Research Services?

Yes No

Will this project receive funding from US Funders (e.g. NIH)? Yes No

If yes, provide further information:

E. Synopsis of Study Progress

1. Progress

Please provide a brief description of the progress to date:

The study has progressed as expected since data collection began in February 2018. Through the recruitment process, 20 students expressed interest to participate in the study, most of whom have now been assessed at least once utilizing the assessment structure.

The primary challenge of the study thus far, has been the learning curve for educators related to application of the new assessment tool in the classroom. While all have been actively attempting to utilize the structure for their assessments, it is only recently that they have become more comfortable with its use on a regular basis.

2. Unanticipated Events

An Unanticipated Event includes any incidents, experiences, or outcomes that have not been previously accounted for in the approved protocol and which place participants, or others, at a greater risk (i.e., physical, psychological, economic, etc.) than was previously anticipated. An Unanticipated Event may have implications for the conduct of the study or the integrity of the research data.

a. Have there been any unanticipated events experienced with this research that have not been previously reported to HREB?

Yes Possibly No

b. If 'Yes' or 'Possibly' is this modification being submitted with an Unanticipated Event Report?

Yes No, please explain:

F. Modifications

In cases where the nature and/or the extent of the proposed modifications are substantial such that the changes result in a study that deviates substantially from the originally approved study or previous modified study, the research ethics board reserves the right to require that a new application form be submitted.

1. Reason for proposed modification(s)

Briefly describe the reason(s) for the proposed modification(s).

While data collection has been successful thus far, due to the nature of the novel assessment structure being introduced, it is only recently that educators have become comfortable with its regular use in the assessment process. By extending the data collection period, we hope to not only increase the quantity of data which is collected but also the quality of the assessments from both the learner and educator perspective.

2. Proposed modification(s) to study

Please outline the details and rationale for the changes along with a brief synopsis of the progress to date. Attach copies of any modified and/or new appendices including recruitment materials, advertisements, consent forms, questionnaires, surveys, etc. ensuring that the changes are marked

Please don't include and don't modify the original approved application form. We have the original approved application on file. Should we require additional documents we will let you know in a timely manner.

The proposed modification to the study would extend the data collection period by one month, beginning on April 9th and continuing until May 11th. As educators have now become comfortable with the use of the assessment structure, by extending the data collection period, we hope to not only increase the quantity of data which is collected but also the quality of the assessments from both the learner and educator perspective.

All the modified appendices that you are submitting must be underlined.

| | |
|---|---|
| <p>a. Modification to Recruitment</p> | <p><input type="checkbox"/>Yes <input checked="" type="checkbox"/>No Rationale: Attach copies of revised recruitment scripts, letters, advertisements, invitations etc.</p> |
| <p>b. Modification to Participants (e.g. pool, group, numbers of, vulnerability, etc.) <i>If there is a change in the level of vulnerability of the participant group(s) include any modifications to the risks and/or protocol to address this change</i></p> | <p><input type="checkbox"/>Yes <input checked="" type="checkbox"/>No Rationale: Attach copies of recruitment tools, consent forms, advertisements etc.</p> |
| <p>c. Modification to Data Collection Method</p> | <p><input type="checkbox"/>Yes <input checked="" type="checkbox"/>No Rationale: Attach copies of revised instruments, surveys, interview or focus group questions</p> |
| <p>d. Modification to Consent</p> | <p><input checked="" type="checkbox"/>Yes <input type="checkbox"/>No Rationale: In the previous consent form, it was expressed to study participants and parents that should the study continue outside of the initially prescribed period they would be provided with an updated consent form to reflect the extension. Attach copies of the revised consent forms, scripts, or letter of information for implied consent.</p> |
| <p>e. Modification to Risk</p> | <p><input type="checkbox"/>Yes <input checked="" type="checkbox"/>No</p> |
| <p>f. Other Modification(s)</p> | <p>Specify changes with rationale: Extension of Data Collection period by one-month beginning April 9th and continuing until May 11th. Attach all applicable details.</p> |

G. Level of Risk

1. Estimate of Risks

Consider any additional inherent risks associated with the modification to your research protocol and complete the table below by putting an X in the appropriate boxes. Be sure to take into account the vulnerability of your target population(s) if applicable:

| Foreseeable Real or Potential Risks of Harm | No change | Increased Risk | Less risk |
|---|-------------------------------------|--------------------------|--------------------------|
| a. Feel demeaned or embarrassed due to the research | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| b. Fatigue or stress | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| c. Other emotional or psychological discomfort | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| d. Social risks, such as stigmatization, loss of status, privacy and/or reputation | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| e. Physical risks such as falls | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| f. Economic risk (e.g. job security, job loss) | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| g. Other risks: (community reputation, workplace morale, family, other third parties) | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

2. Possible Risks

If you indicated (a) to (g) above that any risks are *increased or less*, please explain below:

a. How have the risks changed?

b. What changes to the protocol have been made to mitigate or prevent the risks?

c. If the risks have increased, how have the risks, and the ways that you will mitigate them, been conveyed to the participants?

3. Other Information

Please provide any other pertinent information here, or attach the details to this form:



Mathematical Competency Assessment in Secondary Education

You are invited to ~~participate~~ continue your participation in a the study entitled Mathematical Competency Assessment in Secondary Education that is being conducted by Andrew MacLean.

~~Andrew MacLean is a Graduate Student in the department of Curriculum and Instruction at the University of Victoria and is looking to extend the period of this study by one month, beginning April 9th and ending on May 11th, 2018, in order to collect additional data related to its on-going use of the assessment structure by educators at the Pacific School of Innovation and Inquiry you may contact him~~

~~if you have further questions about the extension of the study, you can contact him by email at You may also contact Andrew's supervisors, Dr. Ulrike Stege and Dr. Todd Milford at respectively.~~

~~As a Graduate student, Andrew is required to conduct research as part of the requirements for a degree in Education. This research is being conducted under the supervision of Dr. Ulrike Stege and Dr. Todd Milford. You may contact them at: _____ respectively.~~

~~Purpose and Objectives~~

~~The purpose of this research project, as part of a larger proposal presented by the Pacific School of Innovation and Inquiry (PSII) to the British Columbia Ministry of Education through the Innovation Grant program, is to aid PSII in building and deploying an interdisciplinary, competency-based assessment system for mathematical literacy that ties learning artifacts to competencies and contexts, allowing for integrated authentic assessment and reporting in a highly personalized learning environment.~~

~~Importance of this Research~~

~~Research of this type is important because the new structure of the revised British Columbia curriculum is moving away from objective oriented assessment and towards competency driven outcomes; however, currently there is no assessment structure that can validly and reliably measure these competencies. This research is of importance because it serves as one of the first attempts to create such a structure, focusing on the area of mathematical literacy which has been studied extensively across the globe.~~

~~Participants Selection~~

~~You are being asked to participate in this study because this research relies primarily on the collection of assessment documents, and learning artifacts, completed by teachers for students in relation to mathematics assessment. Therefore, it will be necessary for teachers to be active participants in this study.~~

~~What is involved~~

~~If you consent to voluntarily continuing your participation ~~participating~~ in this research, that participation will continue to include collection of assessment documents, and learning artifacts, created as part of regular academic exercises by you for your students during the study, which will be analyzed in relation to mathematical competency assessment. Teacher assessment notes could include, but are not limited to, copies of the assessment form developed as part of this study, assessment notes included as part of the grading process of regularly learning artifacts, responses to student reflections, responses to student portfolio entries, and notes regarding student growth outside of the context of learning artifacts.~~

~~Risks~~

~~There are no known or anticipated risks to you by participating in this research.~~

Benefits

The potential benefits of your participation in this research includes the development of more authentic assessment of mathematical literacy in high school students which can aid the BC Ministry of Education in their application of the new Math Curriculum. This has far reaching benefits which will not only influence individual student success but also could help to shift the Educational paradigm in British Columbia and beyond.

Voluntary Participation

Your participation in this research is, and must be, completely voluntary and you are under no obligation to continue your participation participate in the study. If you do decide to participate, you may withdraw at any time without any consequences or any explanation. If you do withdraw from the study your data will not be used in the analysis and the data will be destroyed. Participation in this project will not affect workplace relationships or employment in any way, whether individuals choose to participate or not.

On-going Consent

To make sure that you continue to consent to your participation in this research, I will provide another consent form if the research activities continue outside of the period identified for the study.

Anonymity

In terms of protecting your anonymity, while student and teacher information will be known by researchers during the collection and analysis of the learning artifacts, no identifiable information will be shared in the final, distributed results.

Confidentiality

Your confidentiality and the confidentiality of the data will be protected through multiple methods. Firstly, researchers will work with administration to create a coding sheet which will remove identifiable information from data collected. All hard copy data will also be digitized, with physical copies stored in a locked filing cabinet and all digital files stored on an encrypted hard drive. Coding information will be stored on a separate flash drive and kept in a separate locked location away from the data collected.

Dissemination of Results

It is anticipated that the results of this study will be shared with others through published articles, scholarly presentations, and through a thesis and associated presentations and digital distribution. Should a thesis be developed as a result of this study, it will be available on the Internet via "UVicSpace". Results will also be shared with members of the PSII administration, all study participants and the student body of PSII.

Disposal of Data

Data from this study, in the form of physical copies, will be disposed of either by way of shredding, or return to PSII administration, with all digital data on hard disks being erased and formatted at the completion of the study.

Contacts

For individuals that may be contacted regarding this study please refer to the information at the beginning of the consent form.

In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or ethics@uvic.ca).

Your signature below indicates that you understand the above conditions of participation in this study, that you have had the opportunity to have your questions answered by the researchers, and that you consent to your/your child's participation in this research project.

Name of Participant

Signature

Date

A copy of this consent will be left with you, and a copy will be taken by the researcher.



Mathematical Competency Assessment in Secondary Education

You/your child are invited to continue your participation participate in a the study entitled Mathematical Competency Assessment in Secondary Education that is being conducted by Andrew MacLean.

Andrew MacLean is a Graduate Student in the department of Curriculum and Instruction at the University of Victoria and is looking to extend the period of this study by one month, beginning April 9th and ending on May 11th, 2018, in order to collect additional data related to its on-going use of the assessment structure by educators at the Pacific School of Innovation and Inquiry you may contact him

If you have further questions about the extension of the study, you can contact him by email at You may also contact Andrew's supervisors, Dr. Ulrike Stege and Dr. Todd Milford at respectively.

As a Graduate student, Andrew is required to conduct research as part of the requirements for a degree in Education. This research is being conducted under the supervision of Dr. Ulrike Stege and Dr. Todd Milford. You may contact them at _____ respectively.

Purpose and Objectives

The purpose of this research project, as part of a larger proposal presented by the Pacific School of Innovation and Inquiry (PSII) to the British Columbia Ministry of Education through the Innovation Grant program, is to aid PSII in creating an interdisciplinary, competency-based assessment system for mathematical literacy that allows for authentic assessment and reporting in a highly personalized learning environment.

Importance of this Research

Research of this type is important because the new structure of the revised British Columbia curriculum is moving away from traditional assessment outcomes, such as test results, and towards competency-driven outcomes; however, currently there is no assessment structure that can reliably measure these competencies. This research represents one of the first attempts to create such a structure, focusing on the area of mathematical literacy which has been studied extensively across the globe.

Participants Selection

You/your child are being asked to participate in this study because this research relies primarily on the collection of assessment documents, and learning artifacts (outlined below), from students. Therefore, it will be necessary for students to be active participants in this study.

What is involved

If you consent to you/your child voluntarily continuing your/their participation participating in this research, that participation will continue to include collection of assessment documents, and learning artifacts, created as part of regular academic exercises during the study which will be examined in relation to mathematical competency. Typical classroom work to be collected could include, but is not limited to quizzes, journal entries, self-reflections, concept maps, brainstorming charts, discussion questions and responses, completed worksheets, portfolio entries, written assignments, posters, pictures or visual representation of concepts, PowerPoint presentations, and websites. As PSII is a non-traditional learning environment, the concept of learning artifacts and classroom work may need to be expanded to include other pieces of evidence which demonstrate knowledge attainment. This classroom work will be from regular academic exercises and limited to only those participants whom have agreed to take part in the study.

Risks

There are no known or anticipated risks to you/your child by participating in this research.

Benefits

The potential benefits of you/your child's participation in this research includes the development of more authentic assessment of mathematical literacy in high school students which can aid the BC Ministry of Education in their application of the new Math Curriculum. This has far reaching benefits which will not only influence individual student success but also could help to shift the Educational paradigm in British Columbia and beyond.

Voluntary Participation

You/your child's participation in this research is, and must be, completely voluntary and you are under obligation to continue your participation participate in the study. If you/your child do decide to participate, you/your child may withdraw at any time without any consequences or any explanation. If you/your child do withdraw from the study, your data will not be used in the analysis and the data will be destroyed. Participation in this project will not affect academic standing, relationships or grades in any way, whether individuals choose to participate or not.

On-going Consent

To make sure that you continue to consent to your/your child's participation in this research, I will provide another consent form if the research activities continue outside of the period identified for the study.

Anonymity

In terms of protecting your anonymity, while student information will be known by researchers during the collection and analysis of the learning artifacts, no identifiable information will be shared in the final, distributed results.

Confidentiality

Your confidentiality and the confidentiality of the data will be protected through multiple methods. Firstly, researchers will work with administration to create a coding sheet which will remove identifiable information from data collected. All hard copy data will also be digitized, with physical copies stored in a locked filing cabinet and all digital files stored on an encrypted hard drive. Coding information will be stored on a separate flash drive and kept in a separate locked location away from the data collected.

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It is anticipated that the results of this study will be shared with others through published articles, scholarly presentations, and through a thesis and associated presentations and digital distribution. Should a thesis be developed as a result of this study, it will be available on the Internet via "UVicSpace". Results will also be shared with members of the PSII administration, all study participants and the student body of PSII.

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Contacts

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Your signature below indicates that you understand the above conditions of participation in this study, that you have had the opportunity to have your questions answered by the researchers, and that you consent to your/your child's participation in this research project.

| | | |
|---|---------------------------|----------------------|
| _____ <i>Name of Participant (Student)</i> | _____ <i>Signature</i> | _____ <i>Date</i> |
| _____ <i>Name of Parent/Guardian</i> | _____ <i>Signature</i> | _____ <i>Date</i> |

A copy of this consent will be left with you, and a copy will be taken by the researcher.




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: Andrew MacLean | ETHICS PROTOCOL NUMBER: 17-484 |
| UVic STATUS: Master's Student | Minimal Risk Review - Delegated |
| UVic DEPARTMENT: EDCI | ORIGINAL APPROVAL DATE: 31-Jan-18 |
| SUPERVISOR: Dr. Todd Milford | RENEWED ON: 31-Jan-19 |
| | APPROVAL EXPIRY DATE: 30-Jan-20 |
| PROJECT TITLE: Mathematical Competency Assessment in Secondary Education | |
| RESEARCH TEAM MEMBER Co-Investigators: Todd Milford (UVic), Ulrike Stege (UVic); School Lead: Jessica Asp (Pacific School of Innovation & Inquiry) | |
| DECLARED PROJECT FUNDING: None | |
| CONDITIONS OF APPROVAL | |
| <p>This Certificate of Approval is valid for the above term provided there is no change in the protocol.</p> <p>Modifications 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>Renewals 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>Project Closures 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> | |
| Certification | |
| <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> | |
| <p>_____ Dr. Rachael Scarth Associate Vice-President Research Operations</p> | |

Certificate Issued On: 31-Jan-19

17-484
MacLean, Andrew






Office of Research Services | Human Research Ethics Board
 Administrative Services Building Rm B202 PO Box 1700 STN CSC Victoria BC V8W 2Y2 Canada
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Certificate of Renewed Approval

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| PRINCIPAL INVESTIGATOR: Andrew MacLean | ETHICS PROTOCOL NUMBER: 17-484 |
| UVic STATUS: Master's Student | Minimal Risk Review - Delegated |
| UVic DEPARTMENT: EDCI | ORIGINAL APPROVAL DATE: 31-Jan-18 |
| SUPERVISOR: Dr. Todd Milford | RENEWED ON: 31-Jan-20 |
| | APPROVAL EXPIRY DATE: 30-Jan-21 |
| PROJECT TITLE: Mathematical Competency Assessment in Secondary Education | |
| RESEARCH TEAM MEMBER Co-Investigators: Todd Milford (UVic), Ulrike Stege (UVic); School Lead: Jessica Asp (Pacific School of Innovation & Inquiry) | |
| DECLARED PROJECT FUNDING: None | |
| CONDITIONS OF APPROVAL | |
| <p>This Certificate of Approval is valid for the above term provided there is no change in the protocol.</p> <p>Modifications 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>Renewals 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>Project Closures 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> | |
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| <p>_____ Dr. Rachael Scarth Associate Vice-President Research Operations</p> | |

Certificate Issued On: 31-Jan-20

17-484
MacLean, Andrew





Human Research Ethics Board
 Office of Research Services
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Certificate of Renewed Approval

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| PRINCIPAL INVESTIGATOR: Andrew MacLean | ETHICS PROTOCOL NUMBER 17-484 |
| UVic STATUS: Master's Student | Minimal Risk Review - Delegated |
| UVic DEPARTMENT: EDCI | ORIGINAL APPROVAL DATE: 31-Jan-18 |
| SUPERVISOR: Dr. Todd Milford | RENEWED ON: 29-Jan-21 |
| | APPROVAL EXPIRY DATE: 30-Jan-22 |
| PROJECT TITLE: Mathematical Competency Assessment in Secondary Education | |
| RESEARCH TEAM MEMBERS: Co-Investigators: Todd Milford (UVic), Ulrike Stege (UVic); School Lead: Jessica Asp (Pacific School of Innovation & Inquiry) | |
| DECLARED PROJECT FUNDING: None | |
| CONDITIONS OF APPROVAL | |
| <p>This Certificate of Approval is valid for the above term provided there is no change in the protocol.</p> <p>Modifications 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>Renewals 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>Project Closures 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> | |
| Certification | |
| <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> | |
| <p>_____ Dr. Rachael Scarth Acting Associate Vice-President, Research</p> | |

17-484 MacLean, Andrew

Certificate Issued On: 29-Jan-21

Appendix E

Revised PSII Competency Assessment Framework




(Pacific School of Innovation and Inquiry, n.d.-c)

Context/Objective with Competencies

| Proposed PSII Graduation Framework | | Competency | | | | | | | |
|------------------------------------|--|---------------------|---------------------------------------|-----------------------|------------------------------|--------------------------------|--------------------------------------|--------------------------------|--------------------------------------|
| | | Ecological Literacy | Reading, Writing, Speaking, Listening | Mathematical Literacy | Collaboration and Leadership | Critical and Creative Thinking | Cultural Awareness and Understanding | Information and Media Literacy | Personal Planning and Responsibility |
| Objective/ context | Scientific Process and Application | | | | | | | | |
| | Significant Events and Figures in History | | | | | | | | |
| | Artistic, Literary, and Musical Expression, and Appreciation | | | | | | | | |
| | Identifying and Solving Problems and Making Decisions | | | | | | | | |
| | Physical and Mental Health, Development, and Lifestyle | | | | | | | | |
| | Indigenous Peoples | | | | | | | | |
| | Structured and Unstructured Play | | | | | | | | |
| | Exploring Physical Universe | | | | | | | | |
| | Ethics Awareness and Application | | | | | | | | |
| | Designing and Making | | | | | | | | |
| | Language Acquisition | | | | | | | | |

When planning learning activities with assessment in mind, learners will consider contexts and objectives as well as competencies. Then, when assessment conversations are taking place (formative, early summative, summative, short- and long-term....) competencies can be discussed in terms of context and not just in an abstract way.

PSII Competency Descriptions

| | | |
|---|--|---|
|  | Ecological Literacy | The understanding of closed systems, including the relationships of elements or organisms with one another and with their context or physical surroundings. |
|  | Reading, Writing, Speaking, and Listening | The application of skills and techniques involved in effective communication in today's world. |
|  | Mathematical Literacy | A working knowledge of the language of math, including what numbers and other symbols mean, how space (both real and imaginary) can be explored and described through math, and choosing mathematical strategies to solve problems effectively. |
|  | Collaboration and Leadership | The application of skills, attitudes, and techniques involved in interpersonal relationships, especially in the employ of creativity, analysis, understanding, evaluation, and problem- and solution-finding. |
|  | Critical and Creative Thinking | The awareness and application of different techniques, thought-framing models, and approaches to a variety of challenges, problems, and opportunities. |
|  | Cultural Awareness and Understanding | The development of intercultural competency, including the understanding of the dynamic nature of culture, one's own culture, the relationship of culture to the physical world, and the role of culture on the development of world view. |
|  | Media and Information Literacy | The application of how to share information, how to recognize and analyze bias and purpose, and how to use multiple forms of media to express ideas. |
|  | Personal Planning and Responsibility | The understanding of the balance between rights, freedoms, opportunities, and responsibilities. Developing skills, habits of mind, and knowledge that will allow a person to feel competent in the pursuit of their life goals. |

Ecological Literacy - Competency Assessment Framework

| Indicators <i>Indicators used to help learner/teacher better specify the nature of the learning within each competency</i> | Guiding Questions <i>Questions to help guide formative or summative assessment when discussing learning process or an artifact of learning</i> | <-developing-> | | | |
|--|---|--|--|--|--|
| | | <-expanding-> | | <-fluent-> | |
| | | | | <-proficient-> | |
| <p>Evidence of systems thinking</p> <p>Recognizes the universe as an integrated whole rather than a collection of individual elements</p> <p>Aware of a system's capacity and the factors that influence it</p> <p>Understands the interconnectedness of systems</p> <p>Considers the impact that a behaviour or a decision can have/did have on a system</p> <p>Creates a system in order to meet a need and/or solve a problem</p> | <p>What is a system that you have investigated through your inquiry? A project? A session?</p> <p>What are the components of that system?</p> <p>How do the components of a system interact?</p> <p>How have you used a systems approach to solve or understand a problem or idea?</p> <p>What is a system that you have used to solve a problem or to understand a concept?</p> <p>How do you demonstrate evaluation within the system? (such as make recommendations, judgements, conclusions, predictions)</p> <p>Have you seen a way that multiple systems are interconnected? How?</p> | <p>Knowledge: arrange, define, describe, identify, label, recognize, recall, reproduce, select, repeat, duplicate, list, order, name, match</p> | <p>Comprehension: explain, convert, summarize, paraphrase, illustrate, classify, estimate, express, give examples, infer, locate, select, rewrite, review, translate, discuss</p> | <p>Application & Analysis: use, compute, solve, demonstrate, apply, construct, dramatize, interpret, manipulate, predict, produce, relate, show, analyze, categorize, compare, contrast, modify, interpret, change, illustrate, sketch, write</p> | <p>Synthesis: create, design, hypothesize, invent, develop, arrange, assemble, rewrite, synthesize, collect and categorize, combine, compose, construct, devise, formulate, reconstruct, revise</p> <p>Evaluation: judge, recommend, critique, justify, appraise, argue, conclude, defend, discriminate, evaluate, interpret, predict, value, rate</p> |

Reading, Writing, Speaking, Listening - Competency Assessment Framework

| Indicators <i>Indicators used to help learner/teacher better specify the nature of the learning within each competency</i> | Guiding Questions <i>Questions to help guide formative or summative assessment when discussing learning process or an artifact of learning</i> | <-developing-> | | | |
|---|--|--|--|--|--|
| | | <-expanding-> | | <-fluent-> | |
| | | | | <-proficient-> | |
| <p>Employs writing format appropriate to the learning goal and/or purpose of the writing</p> <p>Uses pre-writing strategies to organize and to plan</p> <p>Chooses language that is purposive, including word choice, style, voice, tone, sentence structure, etc.</p> <p>Communicates main idea(s), either explicitly or implicitly, depending on goal</p> <p>Uses literary devices in writing as appropriate to the goal(s) of the writing</p> <p>Employs editing and revision strategies</p> <p>Uses writing to synthesize/summarize ideas from other sources</p> <p>Uses grammar and other writing conventions as appropriate to context</p> <p>Demonstrates awareness of social and cultural conventions and the impact of word choice on others</p> | <p>What is the intention in what you are writing?</p> <p>How do you plan for writing?</p> <p>What criteria do you use to choose a format or style of writing?</p> <p>How do you seek feedback on your writing?</p> <p>How do you consider purpose and/or audience when you write?</p> <p>What proof-reading/revision strategies do you employ?</p> <p>What are your writing competency goals?</p> <p>How do you measure progress toward goals?</p> <p>What formats are you experimenting with?</p> <p>What strategies/techniques have you used to bring greater depth to your writing?</p> | <p>Knowledge: arrange, define, describe, identify, label, recognize, recall, reproduce, select, repeat, duplicate, list, order, name, match</p> | <p>Comprehension: explain, convert, summarize, paraphrase, illustrate, classify, estimate, express, give examples, infer, locate, select, rewrite, review, translate, discuss</p> | <p>Application & Analysis: use, compute, solve, demonstrate, apply, construct, dramatize, interpret, manipulate, predict, produce, relate, show, analyze, categorize, compare, contrast, modify, interpret, change, illustrate, sketch, write</p> | <p>Synthesis: create, design, hypothesize, invent, develop, arrange, assemble, rewrite, synthesize, collect and categorize, combine, compose, construct, devise, formulate, reconstruct, revise</p> <p>Evaluation: judge, recommend, critique, justify, appraise, argue, conclude, defend, discriminate, evaluate, interpret, predict, value, rate</p> |

Reading, Writing, Speaking, Listening - Competency Assessment Framework

| Indicators <i>Indicators used to help learner/teacher better specify the nature of the learning within each competency</i> | Guiding Questions <i>Questions to help guide formative or summative assessment when discussing learning process or an artifact of learning</i> | <-developing-> | | | |
|---|---|--|---|--|--|
| | | <-expanding-> | | <-fluent-> | |
| | | | | <-proficient-> | |
| <p>Uses strategies to organize and to plan before speaking, when appropriate.</p> <p>Chooses language that is purposive, including word choice, style, voice, tone, sentence structure, etc.</p> <p>Communicates main idea(s), either explicitly or implicitly, depending on goal</p> <p>Chooses structure, content, language, and tone of language with intentionality and to match setting, goal, and audience</p> <p>Awareness of social and cultural conventions and the impact of word choice</p> <p>Responds to others in a way that enhances or builds conversation</p> <p>Employs speaking techniques appropriate to context, subject, purpose, audience</p> <p>Employs self-correction/honing /editing of speech to acquire greater accuracy</p> | <p>How do you select a speaking format to best support your communication/learning goal?</p> <p>What strategies/techniques have you used to improve the effect of your speaking?</p> <p>How do you consider purpose and/or audience when you speak? (vocabulary, tone, cadence, speed, ...)</p> <p>How do you plan for speaking?</p> <p>What tools do you use to support formal speaking? (i.e. debate, speech)</p> <p>How do you use audience response as a gauge for the effectiveness of your speaking?</p> <p>What are your speaking competency goals?</p> <p>How do you measure progress?</p> <p>How do maintain awareness of connotations of words/patterns of speech in a context?</p> | <p>Knowledge: arrange, define, describe, identify, label, recognize, recall, reproduce, select, repeat, duplicate, list, order, name, match</p> | <p>Comprehension: explain, convert, summarize, paraphrase, illustrate, classify, estimate, express, give examples, infer, facts, select, rewrite, review, translate, discuss</p> | <p>Application & Analysis: use, compute, solve, demonstrate, apply, construct, dramatize, interpret, manipulate, predict, produce, relate, show, analyze, categorize, compare, contrast, modify, interpret, change, illustrate, sketch, write</p> | <p>Synthesis: create, design, hypothesize, invent, develop, arrange, assemble, rewrite, synthesize, collect and categorize, combine, compose, construct, devise, formulate, reconstruct, revise</p> <p>Evaluation: judge, recommend, critique, justify, appraise, argue, conclude, defend, discriminate, evaluate, interpret, predict, value, rate</p> |

Reading, Writing, Speaking, Listening - Competency Assessment Framework

| Indicators <i>Indicators used to help learner/teacher better specify the nature of the learning within each competency</i> | Guiding Questions <i>Questions to help guide formative or summative assessment when discussing learning process or an artifact of learning</i> | <-developing-> | | | |
|---|--|--|---|--|--|
| | | <-expanding-> | | <-fluent-> | |
| | | | | <-proficient-> | |
| <p>Employs active listening skills, encouraging/ supporting others to speak/share ideas</p> <p>Seeks understanding; asks clarifying questions</p> <p>Takes into account own bias and how it may affect meaning and/or empathy</p> <p>Demonstrates an awareness of how context, body language, and nonverbal communication inform meaning</p> <p>Employs recording strategies to retain ideas that are received through listening.</p> <p>Listens with attention and to the point necessary to uncover main idea/theme</p> | <p>How did you employ active listening?</p> <p>What tools do you use when listening to support memory? Understanding? Analysis?</p> <p>How do you remain aware of speaking techniques that are being used to persuade?</p> <p>What characteristics of an oral narrative do you most appreciate? Why?</p> <p>What are your listening competency goals?</p> <p>How have you used listening as a way of preparing to speak/write/act effectively?</p> | <p>Knowledge: arrange, define, describe, identify, label, recognize, recall, reproduce, select, repeat, duplicate, list, order, name, match</p> | <p>Comprehension: explain, convert, summarize, paraphrase, illustrate, classify, estimate, express, give examples, infer, facts, select, rewrite, review, translate, discuss</p> | <p>Application & Analysis: use, compute, solve, demonstrate, apply, construct, dramatize, interpret, manipulate, predict, produce, relate, show, analyze, categorize, compare, contrast, modify, interpret, change, illustrate, sketch, write</p> | <p>Synthesis: create, design, hypothesize, invent, develop, arrange, assemble, rewrite, synthesize, collect and categorize, combine, compose, construct, devise, formulate, reconstruct, revise</p> <p>Evaluation: judge, recommend, critique, justify, appraise, argue, conclude, defend, discriminate, evaluate, interpret, predict, value, rate</p> |

Mathematical Literacy - Competency Assessment Framework

| Indicators <i>Indicators used to help learner/teacher better specify the nature of the learning within each competency</i> | Guiding Questions <i>Questions to help guide formative or summative assessment when discussing learning process or an artifact of learning</i> | <-developing-> | | | |
|--|--|---|--|------------|--|
| | | <-expanding-> | | <-fluent-> | |
| | | <-proficient-> | | | |
| <p>Asks questions of a mathematical nature</p> <p>Uses various strategies to approach a problem or situation</p> <p>Recognizes and uses patterns and relationships</p> <p>Makes sense of, relates, uses, and/or creates mathematical representations</p> <p>Uses symbolic, formal, and technical language</p> <p>Uses an understanding of context to guide the mathematical process</p> <p>Uses tools that may assist in implementing processes and procedures for determining mathematical solutions</p> <p>Understands the extents and limits of a mathematical solution</p> | <p>How do you apply mathematics in your learning?</p> <p>How have you used math/math modelling to describe a situation?</p> <p>How have you used mathematics to identify/ formulate/solve a problem?</p> <p>How have you used mathematics to evaluate information or make a decision?</p> <p>How is math present in your inquiry?</p> <p>What are your mathematical literacy goals?</p> <p>How do you measure progress?</p> <p>How has mathematics helped you look at a situation differently?</p> <p>What would you like to be able to use math for in the future?</p> <p>How do you assess/evaluate/choose a math strategy to meet a goal/solve a problem?</p> | <p>Knowledge: arrange, define, describe, identify, label, recognize, recall, reproduce, select, repeat, duplicate, list, order, name, match</p> <p>Comprehension: explain, convert, summarize, paraphrase, illustrate, classify, estimate, express, give examples, infer, locate, select, rewrite, review, translate, discuss</p> <p>Application & Analysis: use, compute, solve, demonstrate, apply, construct, dramatize, interpret, manipulate, predict, produce, relate, show, analyze, categorize, compare, contrast, modify, interpret, change, illustrate, sketch, write</p> <p>Synthesis: create, design, hypothesize, invent, develop, arrange, assemble, rewrite, synthesize, collect and categorize, combine, compose, construct, devise, formulate, reconstruct, revise</p> <p>Evaluation: judge, recommend, critique, justify, appraise, argue, conclude, defend, discriminate, evaluate, interpret, predict, value, rate</p> | | | |

Collaboration and Leadership - Competency Assessment Framework

| Indicators <i>Indicators used to help learner/teacher better specify the nature of the learning within each competency</i> | Guiding Questions <i>Questions to help guide formative or summative assessment when discussing learning process or an artifact of learning</i> | <-developing-> | | | |
|---|--|---|--|------------|--|
| | | <-expanding-> | | <-fluent-> | |
| | | <-proficient-> | | | |
| <p>Articulates a clear vision of the intent of the collaboration</p> <p>Works to develop, agree upon, and achieve shared goals</p> <p>Recognizes possible roles within a group and shares responsibilities</p> <p>Creates opportunities for others to contribute and to learn</p> <p>Contributes something of oneself to a group effort</p> <p>Supports and encourages input from the group and provides constructive feedback</p> <p>Demonstrates habits and behaviours that are a positive model for others</p> <p>Demonstrates flexibility and adaptability</p> <p>Observes behaviour and reflects/responds</p> <p>Demonstrates recognition of individuality/ personality when working with others</p> | <p>How did you demonstrate leadership skills?</p> <p>What are the key components of a successful group process?</p> <p>How did you contribute to a group effort?</p> <p>What role(s) have you/do you prefer to play in a group setting?</p> <p>What processes do you employ in groups to make decisions/set priorities?</p> <p>How do you address conflict in groups?</p> <p>What feedback do you receive from others when working collaboratively?</p> <p>How have you used conflicting needs/views to prioritize group goals or strategies?</p> <p>How have you created/recognized opportunities for others to contribute to a vision?</p> <p>What are your collaboration/leadership competency goals?</p> | <p>Knowledge: arrange, define, describe, identify, label, recognize, recall, reproduce, select, repeat, duplicate, list, order, name, match</p> <p>Comprehension: explain, convert, summarize, paraphrase, illustrate, classify, estimate, express, give examples, infer, locate, select, rewrite, review, translate, discuss</p> <p>Application & Analysis: use, compute, solve, demonstrate, apply, construct, dramatize, interpret, manipulate, predict, produce, relate, show, analyze, categorize, compare, contrast, modify, interpret, change, illustrate, sketch, write</p> <p>Synthesis: create, design, hypothesize, invent, develop, arrange, assemble, rewrite, synthesize, collect and categorize, combine, compose, construct, devise, formulate, reconstruct, revise</p> <p>Evaluation: judge, recommend, critique, justify, appraise, argue, conclude, defend, discriminate, evaluate, interpret, predict, value, rate</p> | | | |

Critical and Creative Thinking - Competency Assessment Framework

| Indicators | Guiding Questions | <-developing-> <-expanding-> <-fluent-> <-proficient-> | | | |
|---|---|--|--|--|--|
| <i>Indicators used to help learner/teacher better specify the nature of the learning within each competency</i> | <i>Questions to help guide formative or summative assessment when discussing learning process or an artifact of learning</i> | | | | |
| Connects ideas in novel ways, or connects previously dissociated ideas | When making connections in a design context that are physical or visual, how are you representing your understanding? | Knowledge: arrange, define, describe, identify, label, recognize, recall, reproduce, select, repeat, duplicate, list, order, name, match Comprehension: explain, convert, summarize, paraphrase, illustrate, classify, estimate, express, give examples, infer, locate, select, rewrite, review, translate, discuss Application & Analysis: use, compute, solve, demonstrate, apply, construct, dramatize, interpret, manipulate, predict, produce, relate, show, analyze, categorize, compare, contrast, modify, interpret, change, illustrate, sketch, write Synthesis: create, design, hypothesize, invent, develop, arrange, assemble, rewrite, synthesize, collect and categorize, combine, compose, construct, devise, formulate, reconstruct, revise Evaluation: judge, recommend, critique, justify, appraise, argue, conclude, defend, discriminate, evaluate, interpret, predict, value, rate | | | |
| Extracts information from explicit and implied sources | How are you using found information while respecting intellectual property? | | | | |
| Develops and/or applies structures/ strategies/ processes/methods to make a decision | How are you practicing skills to advance your knowledge or understanding of tools, approaches, and techniques? | | | | |
| Practices metacognition | How have you turned questions into practice as a means of exploring? (e.g. experimenting with materials/ techniques/ processes/ procedures to achieve a result) | | | | |
| Applies prior knowledge to identify, understand, and solve new problems | If you follow a method/strategy/recipe, are you getting the desired results? If not, how are you using the new information? | | | | |
| Identifies or constructs solution(s) | When facing a critical or creative challenge, what input/resources are you using to work through that challenge? | | | | |
| Evaluates methods/solutions | How do you evaluate potential solutions? | | | | |
| Applies logic to draw a conclusion | What criteria do you use to make decisions? | | | | |
| generates questions to compose line of inquiry | | | | | |
| connects procedures with outcome | | | | | |
| employs imagination/ intuition/ insight/play | | | | | |
| identifies/creates pattern/patterns | | | | | |

Cultural Awareness and Understanding - Competency Assessment Framework

| Indicators | Guiding Questions | <-developing-> <-expanding-> <-fluent-> <-proficient-> | | | |
|---|--|--|--|--|--|
| <i>Indicators used to help learner/teacher better specify the nature of the learning within each competency</i> | <i>Questions to help guide formative or summative assessment when discussing learning process or an artifact of learning</i> | | | | |
| Explores culture with curiosity and sensitivity | In the context of your inquiry, how is culture created? What features comprise culture? | Knowledge: arrange, define, describe, identify, label, recognize, recall, reproduce, select, repeat, duplicate, list, order, name, match Comprehension: explain, convert, summarize, paraphrase, illustrate, classify, estimate, express, give examples, infer, locate, select, rewrite, review, translate, discuss Application & Analysis: use, compute, solve, demonstrate, apply, construct, dramatize, interpret, manipulate, predict, produce, relate, show, analyze, categorize, compare, contrast, modify, interpret, change, illustrate, sketch, write Synthesis: create, design, hypothesize, invent, develop, arrange, assemble, rewrite, synthesize, collect and categorize, combine, compose, construct, devise, formulate, reconstruct, revise Evaluation: judge, recommend, critique, justify, appraise, argue, conclude, defend, discriminate, evaluate, interpret, predict, value, rate | | | |
| Recognizes culture and how it affects attitudes, beliefs, and experiences | How do you deepen your knowledge and appreciation of culture/ a culture? | | | | |
| Acknowledges intra-cultural and inter-cultural diversity | How does your cultural perspective frame your understanding of events/decisions/ relationships/conflicts/intersections? | | | | |
| Enhances knowledge of own cultural origins and/or those of a culture of interest | What is your cultural lens and how is it related to what you value? | | | | |
| Recognizes cultural differences in all aspects of life (art, language, food, economics, tech...) | What are the impacts of cultural diversity/ homogeneity? | | | | |
| Cultivates empathy in such a way as to understand that there are diverse ways to be in the world | What role do you play in creating/preserving/ altering the cultures (s) that you are a part of? | | | | |
| Demonstrates understanding of low/ vs. high-context cultures and situations | | | | | |
| Explores diverse ways of knowing and being | | | | | |
| Explores how morals and values are inherent in cultural framework | | | | | |

Information and Media Literacy - Competency Assessment Framework

| Indicators <i>Indicators used to help learner/teacher better specify the nature of the learning within each competency</i> | Guiding Questions <i>Questions to help guide formative or summative assessment when discussing learning process or an artifact of learning</i> | Competency Level | | | | |
|---|--|--|--|--|---|---|
| | | <-developing-> | <-expanding-> | <-fluent-> | <-proficient-> | |
| <p>Understands the role and functions of media and other information providers in democratic and non-democratic societies</p> <p>Recognizes and articulates need for information</p> <p>Locates and accesses relevant information</p> <p>Evaluates critically information and media content in terms of authority, credibility, and purpose</p> <p>Extracts and organizes information and media content</p> <p>Synthesizes or applies the ideas abstracted from content</p> <p>Communicates ethically and responsibly an understanding of created knowledge to an audience, in an appropriate form and medium</p> <p>Applies ICT skills to process information and to produce own content</p> <p>Engages with media for self-expression, dialogue, and democratic participation</p> | <p>How do you select media format/style to express yourself? Inform yourself?</p> <p>How do you assess safety online?</p> <p>How do you identify "good" sources? (relevant, authoritative, ethical, credible...)</p> <p>How do you extract and organize, synthesize, and make meaning of media content?</p> <p>How do you communicate your intent to an audience? How do you evaluate the degree to which your intent was understood?</p> <p>What are some indicators of author's intent?</p> <p>How does the type/format of media affect how a message is received?</p> <p>How do you show awareness of and sensitivity to your audience?</p> <p>What tools/technologies/skills do you use to produce media? How do you evaluate their effectiveness?</p> | <p>Knowledge: arrange, define, describe, identify, label, recognize, recall, reproduce, select, repeat, duplicate, list, order, name, match</p> | <p>Comprehension: explain, convert, summarize, paraphrase, illustrate, classify, estimate, express, give examples, infer, locate, select, rewrite, review, translate, discuss</p> | <p>Application & Analysis: use, compute, solve, demonstrate, apply, construct, dramatize, interpret, manipulate, predict, produce, relate, show, analyze, categorize, compare, contrast, modify, interpret, change, illustrate, sketch, write</p> | <p>Synthesize: create, design, hypothesize, invent, develop, arrange, assemble, rewrite, synthesize, collect and categorize, combine, compose, construct, devise, formulate, reconstruct, revise</p> | <p>Evaluation: judge, recommend, critique, justify, appraise, argue, conclude, defend, discriminate, evaluate, interpret, predict, value, rate</p> |

Personal Planning and Responsibility - Competency Assessment Framework

| Indicators <i>Indicators used to help learner/teacher better specify the nature of the learning within each competency</i> | Guiding Questions <i>Questions to help guide formative or summative assessment when discussing learning process or an artifact of learning</i> | Competency Level | | | | |
|--|---|--|--|--|---|---|
| | | <-developing-> | <-expanding-> | <-fluent-> | <-proficient-> | |
| <p>Sets goals that support the whole person (mind, body, heart, spirit, joy)</p> <p>Segments goals, as appropriate, into steps or tasks</p> <p>Sets priorities based on importance, urgency, availability of resources, sequence, timing, ...</p> <p>Communicates with others about goals, seeking help or accessing help independently where appropriate</p> <p>reflects on process, including the evaluation and adjustment of a plan as needed, and when making future plans</p> <p>considers the long- and short-term in the planning process</p> <p>Balances responsibility to self and others</p> <p>Differentiates between personal responsibility and group responsibility or the responsibility of another person</p> | <p>What tools do you use when engaged in inquiry-based learning? (eg. portfolio, Trello..)</p> <p>How do you demonstrate awareness of how your actions affect your mind/body/spirit?</p> <p>How do you demonstrate commitment to yourself? Peers? Others?</p> <p>How do you manage/organize your time? Short-term? Longer-term? Set priorities?</p> <p>How do you evaluate your progress toward achieving your goals?</p> <p>What is within your control? What is not? What do you do when something is not in your control but is important to you?</p> <p>How do you consider physical and mental health when setting priorities?</p> <p>How do you self-regulate to optimize your learning? What tools/techniques do you use?</p> <p>How does your awareness of your emotions inform/guide your choices?</p> | <p>Knowledge: arrange, define, describe, identify, label, recognize, recall, reproduce, select, repeat, duplicate, list, order, name, match</p> | <p>Comprehension: explain, convert, summarize, paraphrase, illustrate, classify, estimate, express, give examples, infer, locate, select, rewrite, review, translate, discuss</p> | <p>Application & Analysis: use, compute, solve, demonstrate, apply, construct, dramatize, interpret, manipulate, predict, produce, relate, show, analyze, categorize, compare, contrast, modify, interpret, change, illustrate, sketch, write</p> | <p>Synthesize: create, design, hypothesize, invent, develop, arrange, assemble, rewrite, synthesize, collect and categorize, combine, compose, construct, devise, formulate, reconstruct, revise</p> | <p>Evaluation: judge, recommend, critique, justify, appraise, argue, conclude, defend, discriminate, evaluate, interpret, predict, value, rate</p> |

Appendix F

PSII Prototype Graduation Proposal Presentation

(Pacific School of Innovation and Inquiry, n.d.-c)

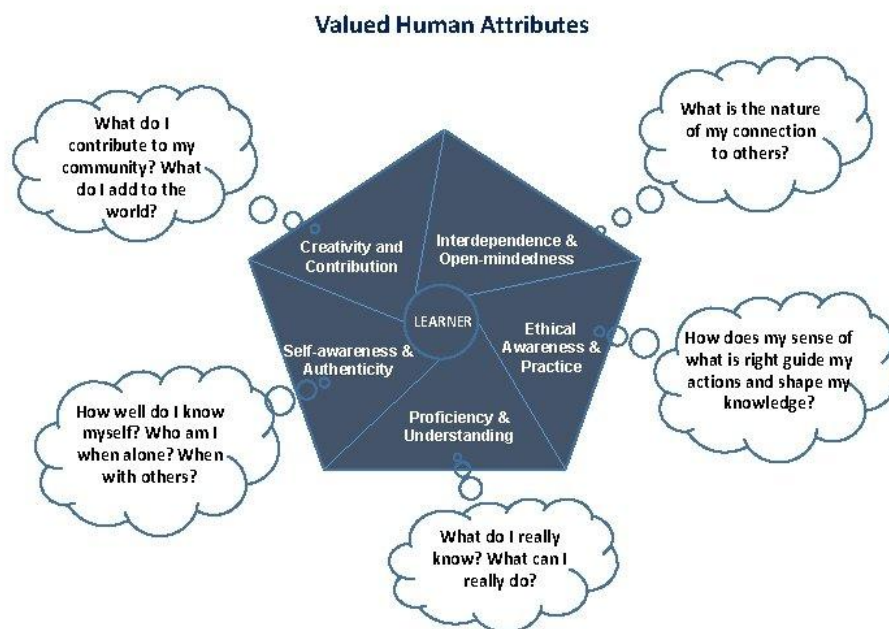
Proposal for a New Prototype Graduation Program

PSII



We propose, and are hoping to implement, a graduation program that is based on new paradigm: one that is informed by current research and thinking among the worlds leading education jurisdictions, including BC.

The paradigm has competencies and high-level objectives, rather than micro-content and behavioural outcomes, as its foundation. These competencies and objectives are informed also by a set of "Valued Human Attributes..."



The competencies and objectives are organized in a framework that sees a highly-personalized curriculum formed by the points at which the two axes intersect...

Our proposed graduation framework...

| Proposed PSII Graduation Framework | | Competency | | | | | | | |
|------------------------------------|--|---------------------|---------------------------------------|-----------------------|------------------------------|--------------------------------|--------------------------------------|--------------------------------|--------------------------------------|
| | | Ecological Literacy | Reading, Writing, Speaking, Listening | Mathematical Literacy | Collaboration and Leadership | Critical and Creative Thinking | Cultural Awareness and Understanding | Information and Media Literacy | Personal Planning and Responsibility |
| Objective/ context | Scientific Process and Application | | | | | | | | |
| | Significant Events and Figures in History | | | | | | | | |
| | Artistic, Literary, and Musical Expression, and Appreciation | | | | | | | | |
| | Identifying and Solving Problems and Making Decisions | | | | | | | | |
| | Physical and Mental Health, Development, and Lifestyle | | | | | | | | |
| | Indigenous Peoples | | | | | | | | |
| | Structured and Unstructured Play | | | | | | | | |
| | Explore Physical Universe | | | | | | | | |
| | Ethics Awareness and Application | | | | | | | | |
| | Designing and Making Things | | | | | | | | |
| Language Acquisition | | | | | | | | | |

The model is based on the concept of "consilience," (the unity of knowledge), where intersection points between objectives and competencies (rather than behavioural outcomes organized by separate subjects) form the basis of assessment and, thereby, what learning is recognized by schools.

| Proposed PSII Graduation Framework | | Competency | | | | | | | |
|------------------------------------|--|---------------------|---------------------------------------|-----------------------|------------------------------|--------------------------------|--------------------------------------|--------------------------------|--------------------------------------|
| | | Ecological Literacy | Reading, Writing, Speaking, Listening | Mathematical Literacy | Collaboration and Leadership | Critical and Creative Thinking | Cultural Awareness and Understanding | Information and Media Literacy | Personal Planning and Responsibility |
| Objective/ context | Scientific Process and Application | | | | | | | | |
| | Significant Events and Figures in History | | | | | | | | |
| | Artistic, Literary, and Musical Expression, and Appreciation | | | | | | | | |
| | Identifying, Approaching, and Solving Problems | | | | | | | | |
| | Physical and Mental Health, Development, and Lifestyle | | | | | | | | |
| | Indigenous Peoples | | | | | | | | |
| | Structured and Unstructured Play | | | | | | | | |
| | Explore Physical Universe | | | | | | | | |
| | Ethics Awareness and Application | | | | | | | | |
| | Designing and Making Things | | | | | | | | |
| Language Acquisition | | | | | | | | | |

This draft model allows for 88 points of intersection. These points where competency and objective meet suggest the content, the processes, and the learning activities that can take place to satisfy the nature of the intersection of the two ideas.

| Proposed PSII Graduation Framework | | Competency | | | | | | | |
|------------------------------------|--|---------------------|---------------------------------------|-----------------------|------------------------------|--------------------------------|--------------------------------------|--------------------------------|--------------------------------------|
| | | Ecological Literacy | Reading, Writing, Speaking, Listening | Mathematical Literacy | Collaboration and Leadership | Critical and Creative Thinking | Cultural Awareness and Understanding | Information and Media Literacy | Personal Planning and Responsibility |
| Objective/ context | Scientific Process and Application | | | | | | | | |
| | Significant Events and Figures in History | | | | | | | | |
| | Artistic, Literary, and Musical Expression, and Appreciation | | | | | | | | |
| | Identifying, Approaching, and Solving Problems | | | | | | | | |
| | Physical and Mental Health, Development, and Lifestyle | | | | | | | | |
| | Indigenous Peoples | | | | | | | | |
| | Structured and Unstructured Play | | | | | | | | |
| | Explore Physical Universe | | | | | | | | |
| | Ethics Awareness and Application | | | | | | | | |
| | Designing and Making Things | | | | | | | | |
| | Language Acquisition | | | | | | | | |

| Competencies | Descriptions |
|--|--|
| Ecological Literacy | The understanding of closed systems, including the relationships of organisms with one another and with their physical surroundings |
| Reading, Writing, Speaking & Listening | The application of skills and techniques involved in effective communication in today's world |
| Mathematical Literacy | A working knowledge of the language of math, including what numbers and other symbols mean, how space (both real and imaginary) can be explored and described through math, and choosing mathematical strategies to solve problems effectively |
| Collaboration and Leadership | The application of skills, attitudes, and techniques involved in interpersonal relationships, especially in the employ of creativity, analysis, understanding, evaluation, and solution-finding |
| Critical and Creative Thinking | The awareness and application of different techniques, thought-framing models, and approaches to a variety of challenges, problems, and opportunities. |
| Cultural Awareness and Understanding | The development of intercultural competency, including the understanding of the dynamic nature of culture, one's own culture, the relationship of culture to the physical world, and the role of culture on world view. |
| Media and Information Literacy | The application of how to share information, how to recognize and to analyse bias and purpose, and how to use multiple forms of media to express oneself. |
| Personal Responsibility and Planning | Understanding the balance between rights, freedoms, opportunities, and responsibilities and developing skills, habits of mind, and knowledge that will allow a person to feel competent in the pursuit of their life goals. |

Why high-level objectives instead of behavioural outcomes?

- 1 To allow for (and to suggest) content, processes, and learning activities **appropriate to individuals and to specific contexts**, without creating outcomes that are susceptible to obsolescence.
- 2 To **avoid the arguments** about what to include and what not to include when the discussion gets closer to the micro-level.
- 3 To allow for **teachable moments**, teacher and learner **creativity**, and the **co-construction of personalized learning paths** that do not need to conform artificially to predetermined minutia.
- 4 To create a framework for assessment that **does not suggest or require comparative metrics**, and one that **supports learning depth as opposed to a “checklist”** of learning outcomes that may or may not encourage depth.

Why an assessment model based on intersections of competencies and objectives rather than courses and outcomes?

To recognize the power of the interconnectedness of disciplines and the resulting consilience that a truly integrated system creates.

Educators will no longer have to stretch to fit valuable learning into pre-packaged courses with fixed outcomes. Nor will they have to invent IDS or BAA courses that are not recognized for entrance into many post-secondary academic or trades programs.

Learners and teachers will be freed to look for what is possible, instead of looking at what is explicitly written or not written in a curriculum document.

This frees educators to employ what we have all learned about good assessment, but have not had a chance to use fully in the current grad program paradigm.

This model also creates an opportunity for a graduation document (transcript) that goes beyond a list of numbers with questionable validity, allowing for an actual **personal learning profile, backed up by a portfolio of selected artifacts**.

This is something that both post-secondary educational institutes and industry would far prefer and trust as an indicator of what a graduate knows, knows how to do, and can offer. This is real accountability.

So how would student
learning be
reported/displayed?
What would a report card
look like?

We would create a **simple single interface for teachers, learners, and parents**, allowing each stakeholder to add, edit, retrieve, and annotate information in real-time.

This would also be the portal to actual **evidence of learning** (something our current system fails to do, leaving us open to questions about standards, inter-rater reliability issues, etc.) in the form of a portfolio...

A single simplified version of the intersection table could be used as an interface for:

- **Teachers** to edit and to view student data related to the intersection point
- **Students** to add artefacts to an electronic portfolio, as related to any intersection point
- **Parents** to see how their child is doing on any intersection point

| | COMPETENCIES | | | | | | | |
|-----------------------------|---------------------|--|-----------------------|----------------------------|------------------------------|------------------------------------|------------------------------|------------------------------------|
| | Ecological Literacy | Reading, Writing, Speaking & Listening | Mathematical Literacy | Collaboration & Leadership | Critical & Creative Thinking | Cultural Awareness & Understanding | Media & Information Literacy | Personal Responsibility & Planning |
| LEARNER OBJECTIVES | | | | | | | | |
| Scientific Process | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| History & Events | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Artistic Expression | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Solving Problems | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Healthy Lifestyle | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Indigenous People | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Play-based Learning | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Communication Tools | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Play | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Physical Universe | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Ethics | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Designing and Making Things | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Language Acquisition | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |

Click on an intersection point to view/edit items that support the depth reported.

Colours or symbols could be used to correspond to different levels of depth to make it very easy to see where learners have been spending their time, and where they might need to spend some more.

Information could include teachers and/or learners' annotations, portfolio artefacts, samples of work showing progression, links to performance standards and other assessment tools...