

Effective Professional Development: Requirements for Technology Integration into Secondary
Science Classrooms

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Abstract

The integration of technology in the classroom is slowly becoming as common as it is in the rest of society. Successful technology integration is necessary to enhance student learning and prepare them for their future at the end of formal schooling. However, secondary science teachers continue to believe that they are the guardians of knowledge for the students, and teacher-led content delivery is the most efficient to enhance student learning thereby limiting teacher use of technology in the classroom. The literature emphasizes the need for student centered learning environments as ideal for technology integration. However, this transition to a constructivist classroom requires teachers to change their pedagogy and beliefs surrounding best learning practices for students, as well as barriers that currently limit technology integration. Effective professional development has the potential to allow secondary science teachers to learn to use the technology, building confidence and providing opportunities for collaboration with peers so they can develop student centered, inquiry-based lessons that successfully integrate technology. This review will examine the requirements for effective professional development for teachers to integrate technology into their classroom, consider the potential barriers that influence this integration and offer some recommendations to integrate technology into secondary science classrooms.

Keywords: technology integration, technology innovation, barriers, enablers, motivation, pedagogy, professional development, technology coach/leader, enacted curriculum, secondary science, inquiry-based, constructivism, flipped classroom.

Table of Contents

Supervisory Committee.....	ii
Abstract.....	ii
Table of Contents.....	iii
List of Figures.....	v
Dedication.....	vi
Chapter 1: Introduction.....	1
Personal Interest.....	2
Background.....	4
Effective professional development.....	5
Barriers to technology integration.....	6
Technology integration in secondary science courses.....	7
Research Questions.....	9
Definitions.....	10
Research Pathway.....	12
Scope of Literature.....	13
Chapter 2: Literature Review.....	15
Methods of Professional Development.....	15
Professional development.....	15
Effective technology professional development.....	15
Discussion.....	19
Teacher Barriers to Technology Integration.....	20
Current barriers.....	20
Reducing Intrinsic Barriers.....	21
Discussion.....	24
Science Classrooms that Promote Successful Technology Integration.....	25
Integrating Technology in Secondary Science.....	25
Technology to enhance student learning in science.....	29
Discussion.....	31
Chapter 3: Project.....	33
What I Have Learned.....	33

PD Workshops.....	34
Technology Coach.....	34
Collaboration.....	35
Learning environment.....	36
Confidence.....	36
Project goal.....	38
Current Technology Professional Development.....	39
Weaknesses.....	39
Strengths.....	40
How Teachers Learn Technology.....	41
Skills that Teachers Need to Build.....	41
Teaching technology.....	41
Integrating technology.....	42
Action Plan.....	44
Rationale.....	45
Teacher resources online.....	45
Digital citizenship & literacy.....	49
Lesson Plan.....	50
Further research.....	51
References.....	53

List of Figures

<i>Figure 1:</i> 1 Year PD Plan outlines the tentative stages of technology integration for teachers....	44
<i>Figure 1:</i> Image capture of the main page of my Google Site for teachers to access resources...	46
<i>Figure 2:</i> Tutorials for various Google applications and specifically Google Classroom.....	46
<i>Figure 3:</i> Tutorials for Google Forms and Google Sites.....	47
<i>Figure 4:</i> Tutorials for using Microsoft Teams and Chromebooks.....	47
<i>Figure 5:</i> Sample Google Classroom set up for teacher discussion and practice.....	48
<i>Figure 6:</i> Page within the website that provides links to twitter and to a discussion for only those teachers involved in the PD.....	49
<i>Figure 7:</i> Digital Citizenship and Literacy information for Teachers.....	50
<i>Figure 8:</i> Prepared lessons for each high school science course are available for teachers to.....	51

Dedication

First and foremost to my husband for enduring the early mornings and weekends parenting and managing our home on his own so that I could complete this program, I could never have done this without you. To my boys, for dealing with me ‘working’ all the time, even during the summers. I missed you too. To my sister, who helped me become a better writer over the course of this program. Finally, to my family, for instilling in me the importance of education from a young age and for letting me miss many Sunday dinners to finish this project.

Chapter 1: Introduction

This review seeks to identify strategies that make professional development (PD) effective for successful integration of technology into the secondary science classroom, by reducing barriers and redefining classroom conditions for learning. PD is an essential component of continuing education in most professions. For teachers, PD is varied but should focus on the needs of the teachers and the school. As various technologies become increasingly accessible for both students and teachers, PD sessions may be offered to educate teachers on utilizing this technology. Despite having some training with the available technology, teachers typically use it as a replacement for traditional school instruments (e.g., digital whiteboard in place of a chalkboard) rather than changing their pedagogy to integrate and innovate with technology. The process of technology integration into the classroom requires teachers to shift their pedagogy to create student centered learning opportunities (Lawless, & Pellegrino, 2007; Whitworth, & Chiu, 2015).

There are extrinsic and intrinsic barriers that may limit teachers from integrating technology to facilitate learning. Intrinsic barriers, including teacher beliefs, pedagogy and confidence are the most challenging to overcome as they require the teacher to change how they teach (Ertmer, Ottenbreit-Leftwich & York, 2006). PD on using technology has become readily available yet there continues to be a disconnect between teachers learning technology and actually integrating it in the classroom (Whitworth & Chiu, 2015). Effective, ongoing and collaborative professional development has the potential to not only equip teachers with the skills for using the technology, but also to continue to support them as they revise their pedagogy and integrate technology into their classrooms. Secondary science teachers who are technology enablers exemplify successful technology integration in student centered learning environments

that enable students to problem solve, think critically and innovate with technology resulting in increased learning and interest in science (Yerrick & Johnson, 2009; Jaipal-Jamani, & Figg, 2015). In the following introduction, I will outline my personal interest in PD for technology integration in secondary science, provide relevant background information and offer the research questions I will explore in the literature review.

Personal Interest

As a secondary science teacher, I understand the constraints that teachers have in academic courses with regards to the amount of content to cover in preparation for the standardized test that looms at the end of each course. Science and technology go hand in hand, as each section of all Alberta science curricula include STS (Science Technology Skills) outcomes. Science could not advance as it has without advancements in technology and vice versa, technology could not advance without science. Science courses, in a constructivist environment, are hands on, engaging lessons in the form of demonstrations and labs. We teach students the scientific process, yet we often provide them with the lab designs and procedures, thereby, effectively spoon feeding them. If we want to develop 21st century thinkers and problem solvers, then we need to develop our lessons to enable students to practice thinking more deeply and more critically. Data collection, which is an essential lab skill, can be performed manually, and it can also be accomplished using digital technologies to expedite the process, leaving more time for analysis and evaluation.

As the designated technology coach for my school, I recognize the need to equip students with the necessary technology skills for success beyond their education, and to do that, teachers need to be integrating more technologies into their classes as a learning tool for students. There are few teachers who are willing to venture outside of their comfort zones and embrace

technology as more than a mere replacement of pen and paper. Most teachers grumble when minor changes are implemented that affect their teaching, such as new grading programs or new digital whiteboards. This results in me coaching teachers in how to use the technology, rather than on innovating with the technology or developing student centered lessons that integrate technology as a tool for learning. Teachers who are keen on learning and integrating new uses of technology in their classes seek my advice and coaching throughout the process.

Over the last 7 years, I have also been the primary organizer of the PD for my school staff. Many PD days have included time for teachers to learn to use new programs, technologies or software licensed by our district. With the fast advancement of technology, I often hear teachers' frustrations with having spent so much time developing lessons and using new software just to see it eliminated and replaced with something newer and more effective requiring them to spend more time revising and re-building their lessons. This replaces time that could otherwise be spent on collaboration and building inquiry-based lessons using technology as a tool. Workshop style PD's are best for learning new technologies and tools and even for demonstrating how to integrate them into classes. I design technology workshops so that teachers can work at their own pace as they learn. Once teachers feel comfortable, I then allot time for teachers to develop a component of a lesson that can be used in their class within the next week or so. Unfortunately, only a few teachers embrace the technology and take the risk of implementing it. Most teachers walk away feeling that they learned something but lack the confidence to integrate it into their classes.

In my experience, teachers feel jaded about learning, let alone implementing, a new technology with their classes because they feel that as soon as they put a lot of time into learning and planning, it will be out of date and they will have to start again. Technology is always

evolving, and it is impossible to tell if products and web tools will be around year after year. Just last year our district signed a contract with Microsoft to activate Office 365 tools, including Microsoft Classroom. Teachers then had to move all their resources from our previous SharePoint into this new format which seemed more promising. Alas, Microsoft decided to go in a different direction and we discovered the Microsoft classroom was no longer in existence and this resulted in spending another professional development session focusing on learning and developing Google classrooms rather than using the time to create technology centered lesson plans.

Because of these experiences, I want to understand how best to educate teachers to not only use technology as a replacement tool, but also to become innovative, or at least develop lessons that encourage innovation among students. How can I ensure that what teachers learn during PD workshops is more readily used? Will the integration of technologies in science actually provide more time for students to have deeper learning experiences? How can I obtain more time for technology coaching in my school so that I can be of better support for teachers who are integrating technologies on a regular basis?

Background

Access to technology has increased in most schools for both teachers and students. This access provides the opportunity for teachers to integrate technology into their lessons for the benefit of learning in their classrooms. Although the potential exists, few educators are doing more than using technology to continue teaching in the same way they always have. Identifying and acknowledging the barriers that limit teachers from integrating and innovating with technology is essential in order to overcome them. Even with improved access to resources, and increased PD, few secondary teachers have created student centered, constructivist learning

environments conducive to technology integration because their beliefs and pedagogy have not changed (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurer, & Sendurer, 2012). Secondary academic teachers with constructivist pedagogies may be limited by the enacted curriculum but might still be able to create student-centered learning opportunities through innovation with technology (Campbell, & Abd-Hamid, 2013). Although PD workshops are beneficial for teachers to learn how to use certain technologies, there is a disconnect between what they learn and their integration of these technologies into their classrooms (Whitworth, & Chiu, 2015). This literature review will examine the requirements for effective PD that reduces barriers and empowers secondary science teachers to create technology integrated, student centered lessons.

Effective professional development. PD is essential for teachers in areas such as keeping current with new teaching strategies, understanding changes to standards, and in learning to use new technologies for education. PD can take place in various forms including observations, lectures, activities and workshops. Perkins (2010) believes that in order for teachers to personalize learning for students, their own learning must also be personalized as adult learners. Through individualized goal setting based on “benchmarks of desired professional practice” (p.16), PD leaders should be tracking progress and collecting data in order to design appropriate, personalized PD.

In order for teachers to integrate technology successfully in their classrooms, the technology PD must be introduced in the context of appropriate pedagogy, within the content area, in a constructivist learning environment and on-site (Bull, Spector, Persichitte, & Meier, 2017; Flick & Bell, 2000; Perkins, 2009). For PD to be successful, teachers initially need to be comfortable with the technology, through practice. They need to experience what students are to experience, and then be given collaboration time to plan how to implement the technologies into

their lessons, or plan lessons around using the technology. The next stage, is implementation in the classroom (Claesgens et al., 2013). This stage ties the teacher PD to student learning, it is here where researchers determine the success of the professional development.

Reaching the point of ongoing technology integration in the classroom requires a change in teacher pedagogy that allows for student centered learning environments. This is not a process that occurs after a single PD session. There are two key factors that will allow this transition to take place: 1) school technology leadership and support and 2) teacher's openness and motivation to integrate technology into the classroom (Claesgens et al., 2013). With positive technology leadership and support from school administration, teachers are granted time to develop their abilities with technology use and collaborate with like-minded teachers upon completion of formal technology training (Claesgens et. al, 2013). Additionally, teachers who went into the technology training PD with an open mind and willingness to adjust their pedagogical beliefs will be more likely to experience successful technology integration into their classrooms (Claesgens et al., 2013). The ultimate indicator of effective technology professional development is increased student learning and understanding through the use of technology in a student-centered learning environment.

Barriers to technology integration. Sherritt and Basom (1996) stated that the demand for technology literate employees is increasing and schools are doing little to prepare students for the information age. Educators continue to educate students as they did during the industrial age (Gorder, 2008). Ermter (1999) outlined numerous barriers that are preventing teachers from integrating technology into their classes such as equipment, time, training and support that are missing or inadequately provided. These are considered first-order barriers. While many of these are no longer major barriers, Ermter (1999) believes that if they are, most can be worked around

with adequate funding. The second-order barriers that Ertmer (1999) outlined are those that are intrinsic to teachers, including their beliefs, confidence and pedagogy relating to how technology should be used. Second-order barriers are more challenging to overcome as they require change from individuals that can only be controlled by the individual themselves.

Teachers require PD, resources, support and time in order to begin to overcome the barriers they face. Not only do they need to know how to use the technology, but they must also be willing to change their pedagogy in order to create a constructivist learning environment for students. Teachers who are exemplary in their technology integration practice are those who have developed “learner centered, constructivist environments” (Ertmer, Ottenbreit-Leftwich & York, 2006, p. 55). However, technology integration into secondary classrooms continues to pose challenges even for those teachers who strive to develop constructivist classrooms due to the constraints of the enacted curriculum. This is what Ertmer et. al (2012) has called a barrier threshold, where despite beliefs, technology integration is limited due to factors outside of the teachers’ control. Effective professional development coupled with peer collaboration and continue support will educate teachers in the use of the technology, within the science context which in turn will build confidence and increase motivation to integrate the technology (Bull, Spector, Persichitte & Meier, 2017).

Technology integration in secondary science courses. Science and technology are linked in the Alberta science curricula (Alberta Education), yet teachers spend little time integrating technology into science lessons and labs. Science advances can only be made through advancing technology and technology is improved through our understanding of science; yet, science educators fail to integrate technology into science learning on an ongoing basis (Guzey & Roehrig, 2012). It is essential that students understand and experience some of the technology

enabling scientists to learn more about the world around us. Science lends itself to inquiry-based lessons which leads students to develop 21st century skills, including problem solving and critical thinking, both of which are skills in high demand by employers. Even with this awareness, science teachers continue to run their classrooms in a traditional format: teacher-led with cookie-cutter labs dispersed throughout, and textbook questions and worksheets for homework practice. One main reason is that secondary science courses are packed with enacted curricular outcomes set out by the provincial government. The standardized exam looming at the end of each course leaves teachers with little additional time for student inquiry. While there is still some content that must be taught in a traditional format, there are numerous topics that can integrate technology into inquiry-based learning opportunities.

The first course of action is to ensure that the teachers are comfortable with the science content prior to integrating technology (Guzey & Roehrig, 2012). Secondly, it is crucial to develop a professional development strategy that provides teachers time to learn the technology, time to create lessons in a collaborative environment and support during implementation so that teachers feel confident with using and implementing the technology tools. Teachers must believe that inquiry-based learning is the best practice for learning and understanding science if the integration is to be successful (Whitworth & Chiu, 2015). Initially, the process for the creation of a single lesson may take the most time, but with ongoing support, teachers will be able to revise their pedagogy to create student centered, inquiry-based learning opportunities that integrate technology for the purposes of science.

Inquiry-based learning is one method teachers might use by providing students with a problem to solve, and it is up to the students to use technology and science tools to find answers. Using computers and personal devices, students can access research to help them develop a lab

design as they begin the scientific process. There are a multitude of science technology tools that may be used to perform and collect data in science including digital microscopes, virtual labs, digital probe ware, and geospatial tools. Students can use social media to ask questions globally and use simple programs such as excel to help collect and analyze data. This in turn, develops collaboration skills, personalizes learning and may motivate students to dig deeper into the topic (Dabbagh & Kitsantas, 2012).

Integrating technology is not about the type of technology being used, it is how the technology is being used to enhance student learning, and develop collaborative and 21st century skills (Chien-hsing, Yi-Ting, Ji-Tong & Wen-Hua, 2012). Realistically, it is difficult, due to instructional time constraints, to complete inquiry on a regular basis at the secondary level. An alternative strategy is to develop a flipped learning environment, where teachers provide resources for students to view and learn ahead so that class time may be used for deeper exploration of the topic (MacKinnon, 2015). This type of technology integration requires students to have access to technology outside of the classroom, which may be a barrier to this type of learning environment for some students. Placing the learning in the hands of the students should, theoretically, develop intrinsic motivation in students to learn and inquire in science. This in turn increases understanding of concepts and interest in science, promotes problem solving, critical thinking, and improves academic results (Inan & Lowther, 2010).

Research Questions

The empirical literature reviewed in order to determine the best strategies for integrating technology into secondary science classrooms was guided by the following three areas of focus:

1. What methods of professional development enable teachers to integrate technology in their classrooms?

2. How can professional development reduce the barriers limiting teachers from integrating technology in their classes?
3. How can professional development redefine classroom conditions to promote successful technology integration in secondary science classrooms?

Definitions

In order to fully understand all aspects of technology integration into secondary science classrooms, it is essential to define the following terms: *technology integration, technology innovation, barriers, enablers, motivation, pedagogy, professional development, technology coach/leader, enacted curriculum, secondary science, inquiry-based, constructivism, and flipped classroom.*

Technology Integration refers to the use of technology in the classroom, seamlessly by both the teacher and students for the purpose of learning (Hew & Brush, 2007).

Technology Innovation utilizes available technology for creating and developing (Zhao, Pugh, Sheldon & Byers, 2002).

Barriers are divided into first and second-order barriers. *First-order barriers* refers to extrinsic barriers outside of the teachers control limiting technology integration, including access to resources, training and support. *Second-order barriers* refers to barriers intrinsic to the teacher that limits their integration of technology including pedagogy, beliefs and motivation (Ertmer, 1999).

Enacted Curriculum is the set curriculum developed by the provincial curriculum, referred to as the *Program of Studies* in Alberta.

Secondary Science refers to sciences taught in grades 10-12, including general science, chemistry, biology and physics.

Enablers are the opposite of *barriers*, factors that enabled the integration of technology and can be either extrinsic or intrinsic (Ertmer et al., 2006).

Professional Development (PD) refers to any opportunity for teachers to learn, or further develop skills and strategies to improve their teaching. PD can occur in multiple formats including observation, lectures, workshops and activities (Lawless & Pellegrino, 2007)

Technology Coach/Leader refers to an exemplary technology-using teacher or administrator responsible for working with teachers as they learn, and improve their use and integration of technology in the classroom.

Inquiry-based is a method of learning where the teacher or students pose a question and learning occurs as students seek out the answer using various methods of research and the scientific process.

Constructivism is the theory that knowledge is relational and the best learning occurs through experience and collaboration.

Motivation can be either *intrinsic* or *extrinsic*. *Extrinsic motivation* refers to an external source causing drive in a person to achieve a goal. *Intrinsic motivation* is an internalized desire to achieve a goal.

Pedagogy refers to the methods and beliefs that a teacher believes is the best practice for teaching and for student learning.

Flipped Classroom is a concept that requires students to read and watch videos to learn a concept on their own, and use class time to practice and extend into deeper learning daily. Flipped learning refers to individual lessons that require students to learn independently from teacher-provided resources so that class time can be used to deepen learning.

Research Pathway

To begin the research, I used the University of Victoria online library. I began with searching ‘technology integration in secondary science classrooms’. I narrowed the search to include only ‘full article online’, ‘peer reviewed’ and ‘journal articles’. This brought up many articles with a focus on beliefs, so I further narrowed the focus to search for ‘beliefs in technology integration in secondary schools’ and ‘barriers to technology integration in secondary schools’ as the lack of technology integration is an issue for most secondary teachers. Many of the articles in both these categories are from 1999-2012. Although the articles are less recent, most of the barrier outlined remain current. Much of this research is referenced in more recent articles on technology integration in secondary schools. I felt it important to include some of these because it demonstrates the lack of progress our education system has made with integrating technology into classrooms as more than a replacement tool for traditional teaching instruments. I used the same statements to search for peer reviewed articles in Google Scholar.

Once I felt I had sufficient articles focusing on the barriers and beliefs of technology integration, I read through them. A key point that stood out is that if a teacher lacks the confidence and skills, it doesn’t matter what type of technology the school has invested in, they will not integrate it. Teachers will not integrate technology if they do not have adequate support. This brought me to considering professional development. Even if a multitude of professional development is offered, I wanted to understand why teachers are not using what they learned. I began my search on both UVic and Google Scholar for ‘Professional development for technology integration’. Most articles came up with a focus on elementary schools, so I further narrowed to including secondary teachers. I found many focusing on effective professional development, outlining the disconnect between the PD session and teachers integrating

technology. This search also brought up a number of case studies that tracked small groups of teachers from professional development on technology to teachers using it in the classroom, those of which were successful cases had ongoing support from peers and time allotted to developing student centered lessons. Finally, I completed a few searches to find how teachers are using technology in secondary science classrooms, this brought up research that focused on specific technologies such as geospatial tools, and microscopes and how they are successfully integrated into inquiry-based lesson in science.

Scope of Literature. I was pleased to find a large number of articles on my topic. Of those, I selected thirty-three; some for use as background information for myself and some to use for citations. As I began my focus on beliefs and barriers, I found many from the same authors (such as Ertmer, P., Zhao, Y., and Hew, K.F.) who have been researching technology integration since the 1990's. Most second-order barriers that Ertmer outlines have been referenced in numerous more recent articles of hers and other authors as some are still barriers in 2017. Over the course of this century, there has been advancement in technology and improved access in schools, but the integration is still an issue for most secondary teacher's due to their pedagogy and the lack of support between PD and actual integration. There are a number of articles that reference Michael Fullan (2006), an author and educator who believes education requires reform to become constructivist learning environments if students are going to develop 21st century skills that are most desired by employers. The subsequent section will discuss the literature that demonstrates how effective professional development can shift pedagogical beliefs enabling secondary science teachers to integrate technologies into their classroom in order to increase student engagement, intrinsic motivation and collaboration, and to develop 21st century skills all while learning the enacted curriculum.

Chapter 2: Literature Review

“Your life as a teacher begins the day you realize that you are always a learner”

– Robert John Meehan

This focus of this review will cover the requirements of effective professional development (PD) for successful technology integration in secondary science classrooms. Technology integration in the 21st century must be for more than simply low-level uses like supporting instruction, it must be used to enhance student learning (Ertmer & Ottenbreit-Leftwich, 2010). I have assembled empirical studies and literature that outline the requirements of effective PD geared towards 21st century technology integration. It is essential to recognize the process teachers must undergo to integrate technology consistently as well as evaluate the success of changes. I will first outline the requirements for effective PD for technology integration. Secondly, I will address the barriers that are limiting teachers from transitioning their learning in PD sessions to the classroom and identify PD strategies that will reduce those barriers. Finally, I will discuss how effective PD can create the classroom conditions necessary for technology integration in secondary science classrooms.

It is essential to note that there are few empirical studies on professional development that provide quantitative evidence of increased student performance through formative assessment. The literature identifies success of effective professional development if teachers implement what was learned through the course of their PD. Research studies that provided evidence of improved student achievement had small numbers of teacher participants and were focused on a single task or technology to be implemented. Studies that demonstrated proof of effective PD collected their data directly from the teachers involved in their studies through surveys and interviews.

Methods of Professional Development

There are a multitude of professional development methods and formats that exist. This section of the literature review will address the first research question posed: What methods of professional development enable teachers to integrate technology in their classrooms? To answer this question, I will review the types of PD that are currently available for teachers to learn technology, and what effective PD should be for teachers who are seeking to integrate technology.

Professional development. PD is an essential part of life-long learning for teachers to ensure they are current with new research and strategies that improve teaching and learning in the classroom (Lawless & Pellegrino, 2007). There are various types of PD available for teachers depending on the purpose. Technology PD is often offered in the form of a workshop where teachers learn to use and experience the latest technology intended to improve student learning (Claesgens et al., 2013). The workshop PD model is essential for teachers to become familiar and possibly even comfortable with the technology, yet, for many educators this single opportunity is insufficient to result in any changes in the classroom (Claesgens et al., 2013). Fishman, Marx, Best, and Tal (2003) and Stiles, Mundry, Love, and Hewson (2010), both identified the earmark of effective PD is teachers actually putting into practice what they learned, which in turn should improve student learning (as cited in Whitworth & Chiu, 2014). Workshops are only the first step in a long process to integrate technology. Teachers must have clear goals, peers with whom to collaborate and ongoing mentorship through the integration process (Lawless & Pellegrino, 2007).

Effective technology professional development. Effective PD models the style of learning that is best for students, after all, teachers are lifelong learners and professional

development is meant for learning (Perkins, 2009; Whitworth & Chiu, 2015). PD that is going to be beneficial and result in real change must occur in stages, over the course of time with collaboration, support and mentoring throughout the process. Charles & Kolvoord (2016) discussed 4 stages of professional development that must occur before a teacher is consistent with their use of technology in the classroom: entry, adopt, adapt and innovate (as cited in Rubino-Hare et al, 2016). The PD process should begin with teachers gaining comfort with the technology in a collaborative workshop, this is the entry stage. The adoption stage, as outlined by Smylie, Showers, Joyce & Bennett is best achieved through collaboration with teachers and with guidance from a mentor to implement the technology integrated lesson accordingly and finally reflecting with the same collaborators on the success and areas for improvement with the technology integration (as cited in Lawless & Pellegrino, 2007). The length of the process is dependent on the individual and their motivation for change and technological skills. Individualized PD allows for all educators to participate with an increased opportunity for success (Perkins, 2009). The ideal learning environment for students is that which is personalized, allowing students to learn what is required using the time and strategies that work best for them.

With this in mind, teacher learning should be considered with the same individualization (Perkins, 2009; Lawless & Pellegrino, 2007). PD that is aligned with the classroom practice allows teachers to experience the same methods of learning that their students will experience (Penuel, Fishman, Yamaguchi, & Gallagher, 2007). The way in which teachers learn technology, should exemplify the way students should learn and use technology, in a student led learning environment (Claesgens et al, 2013). Charles and Kolvoord suggest this will increase the chances that teachers will adapt technology integration into their classes and with practice and reflection,

they may become innovative (as cited in Rubino-Hare et al, 2016). If teachers are going to innovate with the use of technology, they need to create their own lessons that integrate technology. This is most likely to occur in collaboration with peers through phases of reflection and improvement (Rubino-Hare et al., 2016; Guzey & Roehrig, 2009; Whitworth & Chiu, 2014; Claesgens et al., 2013).

Workshops. It is essential that teachers are comfortable with the technology they want to implement. Educators should not only be familiar with how to use the technology, but also how to evaluate outcomes when using new technologies (Bull et al, 2017). Bull et al (2017) identify that workshops intended to teach a new technology should be content focused and in the pedagogical format best suited for technology integration. Although workshops are ideal for teachers learning to use a piece of technology equipment or software, teachers still find it challenging to integrate the information into the classroom. Workshops that allow teachers to learn and practice technology at their own pace within the subject they teach allow for a more personalized learning environment and an increased chance that it will be used in the classroom (Lawless & Pellegrino, 2007). Subject specific workshops should be provided for the initial technology learning; however, they must be paired with mentorship, time and collaboration (during and after the workshop) if teachers are going to successfully implement technology for student learning (Bull et al, 2017; Perkins, 2009; Claesgens et al, 2013; Whitworth & Chiu, 2014).

Mentoring and Coaching. The stages of implementing technology learned in PD should be paired with ongoing coaching and mentoring. Claesgens et al. (2013) found that the initial format of teacher PD can vary, ultimately it is incorporating a mentoring program for teachers that provides additional incentive for them to continue to learn and integrate the technology that

was presented at a PD. Just as educators will teach a concept and continue to support and guide students so that they have a better understanding of a concept, teachers require the same mentoring and coaching so that their learning is ongoing. This extension from the PD session provides support and encouragement for teachers as they work to integrate technology into their classroom. Providing individually tailored PD through coaching and mentoring can support teacher to make drastic changes to their teaching. (Whitworth & Chiu, 2014). This form of PD requires additional time for both the teacher and their mentor so that the teacher can feel supported as they begin to take the risk of integrating technology (Whitworth & Chiu, 2014). Ongoing mentoring and coaching PD support is required as new software and technologies are made available. This level of coaching requires a leadership that is in favour of integrating technology in the classroom at both the school and district level as it requires additional time and resources (Whitworth & Chiu, 2014).

Collaboration. Effective professional development requires that teachers work together to implement new strategies in their classes in order to improve student learning. Whitworth & Chiu (2014) advise that active, collaborative learning of technology must occur in the context of the curriculum content to ensure that the technology can be more readily integrated by teachers. Research performed by Johnson et al. shows that teacher collaboration at the whole-school level that is sustained and collaborative yields positive effects on student achievement in the second and third years, but not in the first as it takes time for teachers to fully implement, evaluate and improve the integration (as cited in Whitworth & Chiu, 2014). Through collaboration, Zeichner believes that teachers can prepare and implement lessons but should also conduct self-study research within these groups to analyze their learning and practice in order to continually improve (as cited in Guzey & Roehrig, 2009). Collaboration fosters professional development as

it creates a supportive environment and allows teachers to reflect and improve on their classroom practice allowing technology integration to occur authentically (Guzey & Roehrig, 2009).

Evaluation/Reflection of Professional Development. Evaluating the effectiveness of a PD is typically done through survey's essentially asking for their perspective on the PD. Surveying how teachers feel the PD benefitted them does not evaluate how effective the PD was for teacher to change their pedagogical approach or implement them into their classroom, we only know how they felt about the PD (Desimone, 2009). The only way to judge the effectiveness of PD is by evaluating any change made in the classroom. (Lawless & Pellegrino, 2007). Ultimately, student success is still based on standardized testing, even if the outcomes are met through constructivist learning and 21st century skills are developed, which is difficult for teachers to measure quantitatively (Rubino-Hare et al., 2016). Teachers can evaluate the effectiveness of the PD process through reflection with colleagues following implementation to assess student learning in order to improve their practice (Claesgens, et al., 2013). Teachers who are supported with increased time, learning opportunities and mentoring are more likely to engage in deeper reflection so they can improve the integration of technology through practice (Rubino-Hare et al., 2016).

Discussion. Charles and Kolvoord (2016), argued that effective professional development for technology integration occurs in stages (as cited in Rubino-Hare et al., 2016). The literature clearly outlines the need for teachers to first be comfortable with their subject content and the technology through workshops. Teachers need to learn the technology in a learner-led workshop in collaboration with peers who will work together to develop and integrate lessons that incorporate technology as a learning tool. The goals for technology integration should be developed along with a planned schedule for further collaboration, evaluation and

reflection on the integration. Mentorship and reflection coupled with ongoing PD time increases the chances of successful technology integration (Rubino-Hare et al., 2016; Guzey & Roehrig, 2009; Whitworth & Chiu, 2014; Claesgens et al., 2013). Amalgamating suggestions from various pieces of literature, I can conclude that a well-developed PD plan that flows from workshops to collaboration, reflection that includes coaching and practice will be most effective for teachers to integrate technology into their classrooms with confidence and success.

Teacher Barriers to Technology Integration

“It is never too late to become reasonable and wise; but if the knowledge comes late, there is always more difficulty in starting a reform.”

– Immanuel Kant, *Prolegomena to Any Future Metaphysics*.

Effective PD can go a long way in guiding teachers as they integrate technology in their classes. For many teachers, it is not this simple. There are a multitude of barriers, both extrinsic and intrinsic to the teacher. This section will answer the second question: How can professional development reduce the barriers limiting teachers from integrating technology into their classes? I will begin by outlining the barriers that have been identified in various studies that are currently limiting teachers from integrating technology and then focus on PD strategies that can help teachers overcome intrinsic barriers as suggested in the literature.

Current barriers. Successful technology integration, according to the Technology in Schools Taskforce, requires “incorporation of technology resources and technology-based practices into the daily routines, work, and management of schools” (as cited in Lawless & Pellegrino, 2007, p. 577). Access to resources and the incorporation of technology practices in schools and classrooms varies as there may be barriers that make technology integration challenging. Ertmer (1999) outlined two categories of barriers that may limit teachers from

integrating technology into their classrooms: first-order barriers are factors that are extrinsic to teachers, and second-order barriers are those that are intrinsic to teachers. Extrinsic barriers include access to resources (hardware and software), professional development, training, and support from peers and leaders. Intrinsic barriers include teacher beliefs, pedagogy, confidence, knowledge, and skills with the use and implementation of technology in the classroom (Ertmer, 1999). Access to resources, professional development and training has increased thereby drastically reducing the extrinsic barriers standing in the way of technology integration (Ertmer & Ottenbreit-Leftwich, 2012). However, there is a clear disconnect between the PD session and actual classroom integration. Despite learning and becoming comfortable with the technology in a PD workshop, teachers continue to struggle with 21st century technology integration. This is due, in part, to intrinsic barriers that are more challenging to reduce as it requires teacher change: a “change in teacher beliefs, understandings and/or practices” (Whitworth & Chiu, 2014, p. 123). Teachers may also lack the skills and confidence needed to facilitate student centered discussion and reasoning (Zalles & Manidakos, 2016). The disconnect from PD to classroom may also be due to extrinsic factors including a lack of: clear goals, mentoring, coaching and opportunities for collaboration from the PD workshop through to the actual integration.

Reducing intrinsic barriers. In order for teachers to reach the point of technology integration in their classroom, a series of three events must occur: Firstly, teachers must be comfortable with the content as well as the technology they are going to integrate which is often met by only a handful of teachers. Experienced teachers have superb content knowledge and know how technology can be integrated, whereas newer teachers may be more comfortable with the technology but have less classroom experience to know how to use technology as an instructional tool (Ertmer et al., 2006). Secondly, individual teacher pedagogy must allow for

technology integration, that is, a teacher who teaches in a collaborative, student-led learning environment already has the set up required for integrating technology (Whitworth & Chiu, 2014; Ertmer, 2005). Hermans, Tondeur, Valcke and Van Braak believe that teachers who are guardians of content and teach in a teacher-led setting will need to change their beliefs and practices if they are going to integrate technology successfully for higher level learning (as cited in Hew & Brush, 2007). Professional development geared to reform teacher practices, needs to have deeper engagement than a basic workshop in the initial stages of technology integration (Penuel et al., 2007). Lastly, the third component of professional development that needs to be included to reduce intrinsic barriers is support from leadership and colleagues. This type of PD is best offered as facilitated planning time, collaboration, and support for successful technology integration.

Content & technology knowledge. Teacher knowledge, as outlined by Borko and Putnam (1995), is the key to how a classroom will operate, what students will learn and how they will learn it. Their knowledge will affect all the decisions made regarding their teaching and student learning (as cited in Ertmer & Ottenbreit-Leftwich, 2010). Shulman (1986) suggested teacher knowledge can be broken down into more detailed knowledge: content (subject) knowledge, pedagogical (teacher methods) knowledge, pedagogical content knowledge, curricular (materials & media) knowledge, context knowledge and knowledge of goals (as cited in Ertmer & Ottenbreit-Leftwich, 2010). Technology knowledge falls under curricular knowledge; however, the use of technology today should be used to enhance student learning. Teachers with strong content knowledge, and a constructivist learning environment will likely be able to integrate new technology more effectively as their pedagogical content knowledge already suits 21st century learning (Ertmer, Ottenbreit-Leftwich, 2010).

Changing beliefs and pedagogy. Ertmer, Addison, Lane, Ross & Woods (1999) iterate that teacher beliefs about technology for education determine how they will use it in their classes (as cited in Hew & Brush, 2007; Hodges, Gale, & Meng, 2016). Teachers identified intrinsic factors to hold greater influence on their choice to implement technology than extrinsic factors (Ertmer et al., 2006). Essentially, even with technology PD, teachers may not choose to use technology as they lack the intrinsic motivation. PD focused on learning to use technologies is good for building teacher knowledge and skills but is insufficient for changing the way teachers teach. While providing PD on specific technology is essential for some skill building, teachers ultimately need to have the mindset of exploring new technologies on their own. Successful technology integration requires that the teacher believes that the technology can truly enhance student learning and improve their achievement (Ertmer, Ottenbreit-Leftiwch, Sadik, Sendurur, & Sendurur, 2012).

Effective PD trains teachers how to approach new technologies, not simply how to use them so that any teacher with an open attitude about technology integration will be able to introduce it in the classroom. (Bull et al, 2017). Shawnewssy (2005), believes that the journey of a teacher moving to integrate technology requires professional development geared towards redefining their pedagogy and belief (as cited in Hew & Brush, 2007); however, they must be prepared to make this change as “teacher readiness had the highest total effect on technology integration” (Inan & Lowther, 2010). A student led learning environment is best suited technology integration, however if a teachers’ pedagogy is not aligned with this method of student learning, then technology integration will be more challenging if it occurs at all. For many teachers, turning their classroom into a constructivist learning environment is a difficult process, but is required for successful technology integration (Ertmer et al., 2006). Fullan (2006)

believes that PD can provide improvement when participants are motivated both individually and collectively to put in effort to change (as cited in Perkins, 2010).

Leadership and support. Professional development, to be truly effective, must extend beyond the workshop or lecture which requires additional time; this is where leadership will enable or limit the opportunities for teachers to extrapolate their knowledge from PD into classroom practice (Whitworth & Chiu, 2014). A school that enables and encourages the integration of technology will have leadership that has outlined clear goals for technology integration that will promote a collaborative environment of individuals who share similar beliefs. Marzano et al. (2005) suggest that effective technology leaders will also ensure that teachers are provided with time for planning, collaborating and coaching throughout the process of technology integration but are also continually monitoring and evaluating school curriculum and achievement. (as cited in Whitworth & Chiu, 2014).

Discussion. The literature clearly outlines intrinsic factors are rated as most crucial for teachers to change if they are to integrate technology into their classrooms. Appropriate PD can assist teachers in overcoming the barriers preventing them from integrating technology if it is personalized, pertinent, collaborative, and supported by school leaders. PD can also encourage teachers to utilize technology, such as social media, to keep them connected to peers who may teach in different schools but who are seeking to integrate technology in a similar manner (Dabbagh, & Kitsantas, 2012). Ultimately, as studies have shown, teachers need to be open and willing to redefine their pedagogical beliefs and take the risk of integrating technology in their classes. Through effective PD and support, teachers can build confidence in their ability to integrate technology thereby allowing them to become more open to change.

Science Classrooms that Promote Successful Technology Integration

“When we introduce new technologies into our classrooms we are teaching our students twice.”

— Michael Joseph Brown

This section will explore the last research question: How can professional development redefine classroom conditions to promote successful technology integration in secondary science classrooms? I will outline the purpose of technology integration, why it is important and what environment is best suited for successful technology integration. Furthermore, I will provide specific examples from literature as to how technology can be successfully integrated in science.

Integrating Technology in Secondary Science. The advancement of science is a direct result of our continual advancement of technology. Although educators recognize the importance of technology for advancement in society, science teachers have not fully integrated it in their classrooms (Guzey & Roehrig, 2012). Developing 21st century skills such as problem solving, and critical thinking has always been necessary, but they are more important for our students now than ever before. Students must understand that they are life-long learners, that as technologies advance, all aspects of their work and personal life will also evolve over the course of their lifetime and they need to have the skills to learn new technologies (Chu, Reynolds, Tavares, Notari, & Lee, 2017).

Along the same lines, teachers need to not only learn specific technologies but also need to learn how to learn new technologies as there will always be new technologies developed for education and research (Bull et al., 2017). Core subjects continue to be necessary and required; however, within those subjects, students’ needs to develop: learning and innovation skills, information skills, media and technology skills along with life and career skills. While some of these topics require their own courses, many of these skills can be embedded within the core

subjects by revising the content, the delivery and use of technology in the classroom. This requires teachers to be not only proficient in the use of technologies they are integrating into their classes, but also with the subject they are teaching (Bellanca & Brandt, 2010). Teachers who are new to the profession may know content but may be unable to introduce technology in a student-centered learning environment if they lack confidence in the subject matter. It is therefore crucial that PD designed for teachers to integrate technology be presented within the subject area (Jaipal-Jamani & Figg, 2015).

Reforming the manner in which students learn in science, requires a change in the pedagogy and for that, teachers must experience 21st century learning themselves through PD (Desimone, 2009). PD workshops should be developed specifically for educators to experience inquiry-based and project-based learning for themselves, so they can be literate in digital collaboration, and media and information technology while acquiring 21st century skills (Chu et al., 2017). Teachers who have revised their pedagogy to integrate technology in their secondary science classroom have developed student led lessons and perhaps converted their role of ‘teacher’ into that of ‘facilitator’ by adopting a constructivist learning environment where students are collaborating and constructing their own knowledge by engaging in higher order thinking (Wang, Ke, Wu, & Hsu, 2012). Encouraging intrinsic motivation within both teachers and students is the key to authentic learning, because they are interested in the experience, the process and the results of their scientific research (Anastopoulou et al., 2012). Technology integration should enable all types of students to have access to knowledge thereby creating a personalized learning environment (Yerrick & Johnson, 2009). Teachers who are able to use and integrate technology as a tool for learning in a constructivist environment despite existing barriers, are exemplary technology-using teachers. (Ernter et al., 2006).

Constructivist Learning Environments. Exemplary technology-using secondary science teachers have created learning environments that allow students to be the knowledge constructors. This engages students more deeply as they are responsible for their learning because they are creating the questions and finding the answers collaboratively (Wang et al., 2012). There are a multitude of learning methods that are best suited to a constructivist classroom and teachers may select one or more of these methods, or create something entirely new as long as the learning space is one that promotes students led learning (Ertmer et al., 2006). The environment in which students learn has a strong effect on their motivation to learn (Liu, Horton, Olmanson, & Toprac, 2011). Motivation to learn must come from within the students, just as it must come from within the teacher if they want to integrate technology and reform their pedagogy to do so (Perkins, 2010).

Hidi & Harackewicz (2000) believe that providing students instructional materials that give them choice may allow them to feel a sense of autonomy over their learning (as cited in Liu et al., 2011). As long as they believe they can succeed and topic is of interest, there can be motivation. Students need to believe they are capable of taking on the challenge of learning (Liu et al., 2011). A constructivist learning environment can provide the opportunity for students to be motivated to learn in a collaborative, inquiry-based environment (Wang et al., 2012). Inquiry-based and project-based learning are the ideal constructivist pedagogical approaches for science courses as they allow students ask authentic questions and use the scientific method in search of the answers. A collaborative classroom layout is also necessary for the constructivist approach to be successful (Hew & Brush, 2007).

Inquiry Based Learning. The purpose of science is to discover and as such, science teachers should provide authentic opportunities for discovery learning by enabling students to

establish a problem and seek to find a solution (Anastopoulou et al., 2012). Using inquiry-based learning, students are tasked with asking questions and following the scientific process to develop and carry out an investigation to attempt to answer them. In order for teachers to teach appropriately in this manner, a PD workshop presented in a similar manner allows educators to experience the same, so they can guide their students through the process (Winschitl, 2002). Hew & Brush (2007) and Neiss (2005) suggest that using technology as part of their problem-solving process allows students to collect and analyze data more thoroughly using various types of hardware and software, in a collaborative setting similar to real scientists (as cited in Pringle, Dawson & Ritzhaupt, 2015).

Project Based Learning. Similar to Inquiry-Based Learning, Project Based Learning (PBL) allows students to select a topic or issue that they want to investigate (Wang et al., 2012). Just as with the scientific process, there are stages that must be completed in order to achieve their project goal. This process requires students to be accountable to themselves by setting daily goals as well as to their peers with whom they are working on the project (Bell, 2010).

Each of these methods requires the integration of technology as a tool for learning in an environment that is student directed. Developing PD for teachers that promotes constructivist learning environments is challenging unless the teacher is ready and willing to transition their classes for 21st century learning (Chu et al., 2017). Teachers must be confident in their subject area, with the technology and have collaborators and mentors to work with throughout the implementation. Teachers must also be prepared for the fact that transition is slow, and it takes a few years to fully adopt a student led learning environment (Guzey & Roehrig, 2009). Ultimately, students' needs to learn to think like scientists and carry-out investigations as scientists do and evaluate their process through critical thinking, just as scientists do in order to

improve results (Anastopoulou et al., 2012). By using technology tools appropriate for science learning, students can develop the 21st century skills that will allow them to understand and potentially solve global issues (Trowbridge, Bybee, & Powell, 2008).

Technology to enhance student learning in science. Successful technology integration in science classrooms incorporates a variety of technological tools to enhance student learning in a student-led environment (Guzey & Roehrig, 2009). Flick & Bell (2000) proposed five guidelines that should be used to prepare teachers to integrate technology in science:

1. Technology should be introduced in the context of science content.
2. Technology should address worthwhile science with appropriate pedagogy
3. Technology instruction in science should take advantage of the unique features of technology
4. Technology should make scientific views more accessible
5. Technology instruction should develop students understanding of the relationship between technology and science (p. 40).

Access to computers laptops and tablets has become much easier in the last few years and as such, with the right programs, and the internet, students can perform a multitude of investigations using technology as a tool for learning. Students can develop blogs to demonstrate their knowledge on issues in science such as climate change, peer review each other's work or even to collaborate on projects (Wang et al., 2012). MS Word and PowerPoint can be used by students to present their scientific process and results of their inquiry in order to demonstrate their learning (Wang et al., 2012). The internet has a variety of web 2.0 tools, applications and websites that are designed to facilitate inquiry in science. Many sites also offer assessment tools allowing teachers to keep track of student learning (Moore & Huber, 2001). Connecting other

technologies to a laptop such as digital microscopes, digital probeware, and geospatial technology, students can more easily collect and analyze data providing them with more details and insights in their investigations than would be possible without. This can deepen the learning and increase collaboration between students (Jaipal-Jamani, & Figg, 2015; Dickerson & Kubasko, 2007; Zalles & Manidakos, 2001).

Students can also extend their learning by using pictures and digital video to capture details that they might see only by slowing down the video they create during their investigation (Park, 2010). Using tools such as Google Suite, a cloud-based platform allows students to collaborate on their projects and investigations from their own devices at school or home. The ability to acquire and share information instantaneously places the world at the fingertips of the students and allows for limitless collaboration (Foley & Reveles, 2014). Social media can be used for communication and sharing of learning, however it must be carefully managed to be considered beneficial for education (Dabbagh & Kitsantas, 2012). Students can use their smartphones and tablets to record their work and explain themselves, so the teacher can view and provide immediate feedback to students that there may not always be time for during class (Chao, Murray, & Star, 2016). Using personal devices not only increases the opportunity for collaboration between students but can also personalize learning for students to work at their own pace and receive individual instruction and feedback (Ryan, 2016).

Teachers cannot assume that students who are now coined 'digital natives' are naturally skilled at using any of the technologies listed above. As any person, students too require practice with new technologies and software and need to understand the intent of the technology if they are to be motivated to learn (Liu et al., 2011). Teachers must also provide students with the opportunity to experience the technology and learn information and media literacy prior to

assigning any projects (Campbell & Abd-Hamid, 2013). Teachers beginning their journey of technology integration require training, collaboration and support through the integration just as students require training, collaboration and support from their teacher as they become the leaders of their own learning (Liu et al., 2011).

Discussion. Successful integration of technology in secondary science classes, as outlined by the literature, is best suited to a constructivist learning environment. Using technology effectively for inquiry-based learning can contribute to the development of 21st century skills such as problem solving and critical thinking. Teachers should experience PD that incorporates the technology they wish to integrate within a constructivist learning environment that models the intended student environment. Students should be guided in their use of web 2.0, the internet, GPS devices, probeware, digital microscopes, social media and digital video so that the tools are used responsibly and effectively. Although most secondary teachers are bound by set outcomes and standardized testing, teachers can create opportunities for inquiry and project-based learning that integrates technology and inspires and motivates students to learn and engage in scientific discovery.

Conclusion

The literature speaks volumes about the need for professional development to be more than a single workshop that introduces technology to teachers. It is clear that the teacher needs to be ready to reform their pedagogy and beliefs if they are to truly integrate technology in their secondary science classroom. The process of technology integration may take a few years and the journey should be inclusive of time for teachers to collaborate and reflect on their lessons in order to improve (Perkins, 2009). Teachers who set a goal, are intrinsically motivated to receive necessary training with collaborative peers and revise their pedagogy to create a student

centered, technology integrated classroom (Lawless & Pellegrino, 2007). The current requirement of students to achieve enacted curricular outcomes and perform standardized testing does create an extrinsic barrier that prevents any teachers from solely assessing projects to demonstrate student learning. This barrier cannot be brushed aside; however, teachers can develop a student-centered learning environment that incorporates some teacher directed lessons and summative testing so that students not only develop 21st century skills but are also prepared for government exams (Charles, & Kolvoord, 2016).

Project Proposal

The focus of this review was on how effective professional development can help teachers revise their pedagogy and overcome barriers in order to integrate technology in secondary science classes. The literature outlines the need for PD that occurs in stages over a period of time. Each teacher wanting to integrate technology will begin with different skill sets, and learn at their own unique pace, just as students do. I believe that a one-year PD plan that includes scheduled workshops, collaboration time and mentorship that is approved by administration is required for teachers understand their commitment and set the goals. Along with a plan, I intend to create a website that offers links to resources and tutorials, discussion forums for online peer collaboration and sample lesson plans for teachers to use in the beginning stages of technology integration. This will allow teachers to learn technologies at their own pace if required. This website and PD plan designed in this project will be generic as actual goals need to be determined by the teachers and the school. I will provide a sample plan with an example goal; however, this plan and website can be used as a template and resource for any teachers seeking to organize PD plan to integrate technology in science.

Project

What I Have Learned

Technology integration has been improving at a slow pace over the last 2 decades. Despite the increased access to technology, many teachers struggle to use technology for learning in the classroom. The literature I have reviewed points to a number of factors that contribute to the lack of technology integration despite having access and obtaining some technology training. The main factors that stood out include the teacher's intrinsic motivation to want to learn and integrate technology into their classrooms. Teachers need to be open and ready to change their pedagogical beliefs to implement constructivist teacher practices. They need to believe that technology can be used to improve student learning. Professional development (PD) can be an excellent way for teachers to learn the technology, learn how to integrate the technology but primarily learn to shift their pedagogy. PD needs to be designed in such a way that it models the method to be used with students. Teachers require the opportunity to learn the technology in a collaborative setting but also have the support of the administration and their peers as they integrate technology. The process of integrating technology, as suggested by the literature, is more likely to be successful if teachers have the ability to collaborate with like-minded peers with whom to plan, discuss and reflect throughout the implementation process. Furthermore, a mentor or coach should be available for guidance during the course of implementation. Teachers who are comfortable with the content they are teaching are the ideal candidates to begin technology integration for learning. Many new teachers are great with technology but are not always confident with the course material at the secondary level. If the teacher has not taught the subject before, their primary focus tends to be on ensuring that they are

comfortable and familiar with the outcomes of the course, so they can ensure they are meeting those requirements when developing student-led lessons that integrate technology.

PD workshops. PD workshops have become readily available in most urban centers for teachers who want to learn a new technology. Spending three hours learning new technology is just enough time to get a non-tech savvy teacher excited about how the technology can be used in the classroom. My personal experience with workshops is that they are designed to benefit those who learn new technologies quickly and efficiently, so they can begin to determine how to utilize them in their classrooms. Those who take longer to learn new technologies are often excited about the capabilities of the technology, but do not have enough time to learn it sufficiently to be confident with implementing it. Learning something new requires practice in order for the teacher to become familiar and comfortable with the technology before having sufficient knowledge and confidence to integrate it into their classroom. This is crucial because teachers should have the ability to monitor appropriate use of the technology as well as troubleshoot minor issues should they arise when students are using technology. Furthermore, teachers who have developed confidence with the technology will be more likely to understand how a constructivist environment is ideal for technology integration in the classroom. Workshops are a great way for teachers to be introduced to a new technology; however, having a supportive mentor or coach available for guidance and support can be the push needed for teacher to try and integrate the technology.

Technology coach. A school that is supportive to technology integration should assign designated tech time to a technology proficient teacher to coach teachers in their use of technology. After completing a workshop, many teachers walk away with a basic understanding of the technology but are not prepared to use it with students. A designated technology coach can

organize time with participants in order to support and guide them through implementation. Knowing that there is someone to call upon for guidance and troubleshooting may encourage teachers to take the risk of integrating technology into their classes. A coach can also check in with teachers to see how their integration is progressing and how they can be supported. Access to this support is essential for teachers as they build confidence with their use of technology in the classroom. Technology coaches who are actively involved with their teacher's tech use, know how their teachers are using technology in their classes. This knowledge allows the coach to put teachers together in collaborative groups with teachers who have similar technology integration goals. Part of having a coach who is knowledgeable about their staff's technological abilities is that they can group individuals together who learn technology at the same pace. Those who are advanced can be grouped together, those who struggle can move at a slower pace and not feel intimidated by those who learn technology quickly.

Collaboration. Collaboration is the key to many technology integration successes. The literature I reviewed provided examples of studies where researchers worked with teachers who wanted to integrate technology. Those who were independently integrating technology saw less success than those who were collaborating with peers at their same school site. The ideal collaborative group for successful technology integration are those who share similar goals and who work at a similar pace. Furthermore, it is best if the collaborative group work at the same site, or minimally within the same district and have the technology available, and support from school leadership. Goals, learning pace and location are important considerations for a collaborative group because this allows teachers to meet more consistently formally and informally to confer on progress. This creates more opportunities for discussion, planning and reflection on the integration. As teachers, we are often keen to implement new ideas, but we do

not often follow through with formally reflecting or evaluating the success of the ideas.

Collaborating with like-minded peers at the same site, teachers can confer more frequently allowing them to resolve challenges with support rather than feeling unsuccessful and losing motivation with the integration. Teachers each have their own pedagogical beliefs and methods they feel are the best for learning. A collaborative group brings a variety of pedagogical beliefs to the table allowing teachers to see which methods appear to result in more successful technology integration.

Learning environment. The ideal approach to learning science is learning through inquiry. Science discoveries have been made by inquiring minds who have sought to find the answers to their questions. This can be challenging in a classroom setting with outcomes that are clearly defined by the provincially set curriculum. Minimally, teachers should adopt a constructivist learning environment in their classrooms to encourage collaborative learning when integrating technology. As I outlined in the literature review, using technology for learning in a collaborative setting can engage students and motivate them to learn as they are in control of their learning. This type of learning requires students to problem solve and think critically thereby developing 21st century skills. If the pedagogical approach to learning is student centered, it becomes a smooth transition for integrating technology and creating inquiry-based learning opportunities. A teacher whose primary method of instruction is student directed, is likely already confident in their subject knowledge and has a good idea of the outcomes that need to be achieved such that technology integration is not a huge step for them, other than ensuring they are comfortable with the technology.

Confidence. Teachers who have difficulty letting go of control in the classroom may experience more challenges when integrating technology for learning because their pedagogical

beliefs are not aligned with constructivist learning methods. Teachers who fall into this category require a lot more from a technology coach in order to integrate technology. These are the teachers who will attend technology workshops, complain about how much work it is and balk at the idea of using it in the classroom unless they are provided with time to develop their lessons. It is for these teachers in particular that I believe it may be important to have ready-made lesson plans prepared for each subject area on a topic that is simple and integrates technology for learning. The ability to follow a lesson plan that has details right down to how to structure the classroom for the lesson will allow the teacher to witness how students engage with the content when using technology for learning. It is important to note that prepared lessons would be introduced and provided during a collaborative workshop so that teachers could tweak the lessons if required and understand how the technology will promote learning. It is also essential that a coach, or peers who are familiar with the technology are available should any trouble shooting be necessary. Teachers who are new at technology integration are often nervous and worry that the lesson won't work out if the technology doesn't work exactly as it should; having school tech coach to call upon, if necessary, can reduce some of the 'first day jitters'.

Nonetheless, having a 'first-time' lesson developed allows these teachers to focus solely on ensuring they understand the technology, so they can facilitate the lesson. If multiple teachers are implementing the same lesson, within the same day, knowing that they are going to follow up afterwards creates accountability. People are most likely to follow through and take chances if they know they are accountable. They can choose how they want to build on the lesson or leave it as a one-day formative lab or project in order to take the pressure off themselves, should it not go as planned. This flexibility is crucial to reduce the stress and anxiety about trying something

new. It is also important to ensure that this integration is best done in a course that doesn't have a standardized government exam at the end thus minimizing the pressure on the teacher.

Project goal. The studies I reviewed have allowed me to conclude that in order for teachers to embrace technology and integrate it in their classes for the purposes of learning, they must go through an effective professional development process that extends beyond a single workshop or single goal. This process will vary depending on how easily individual teachers learn technology. For those teachers who struggle with technology on a daily basis, considering technology integration for the purposes of learning may seem like a very difficult task, if not impossible. A well outlined structure for PD is essential, that allows the teacher to progress slowly towards simple and basic technology integration. I will outline a process for PD over the course of a school year beginning in September that would allow teachers to build confidence, revise their pedagogical approach when integrating technology with support and guidance while collaborating with peers at the same site. Realistically, this process would require a time commitment for workshops and collaboration, which would need to be approved by the school administration, as the cost of replacement teachers would need to be covered. Lack of support from leadership is an extrinsic barrier that can be difficult to overcome but will vary between schools and districts as outlined in the literature review. For the purposes of this project, I will account for a flexible and supportive school administration who has funds available for teachers for technology PD. Some of the PD time may take place during already scheduled meeting times for PLC's (Personal Learning Communities) as this group of collaborative peers could qualify as a PLC. I will begin by outlining the strengths and weaknesses of current PD from my experience and as I have read in the literature along with identifying how teachers appear to best learn technology. Based on this, I will then outline a month-by-month PD plan that incorporates

workshops, coaching, collaboration and pre-made lessons over the course of one school year that should build confidence for teachers who want to integrate technology but find it intimidating.

My focus will be on high school sciences, but the plan can easily be converted to guide teachers in any subject area at the high school level. My resource website will be generic for any teacher to access resources such as lesson plans and tutorials for varying technologies.

Current Technology Professional Development

Weaknesses. The current focus of professional development for learning technology is done through workshops. These sessions can vary in length from one hour or 6 hours; however, they are almost always limited to a single session. More often than not, the time is spent rushing through showing participants how to use the technology, sometimes providing time to practice, depending on the length of the session. This winds up being enough time for the instructor to showcase the capabilities of the technology to get teachers excited and interested in its' use. Depending on the complexity of the technology, and the amount of time for the workshop, teachers who are technology novices may feel overwhelmed and fall behind, causing them to be frustrated and continue to struggle with the technology. Teachers who are tech savvy will easily keep up and are often good at navigating newer technologies thereby moving at a faster pace. Moving at a faster pace means they are likely to have questions that will change the flow of the workshop and possibly further intimidate those who learn technology at a slower pace. This can be difficult for the workshop leader to manage if they did not plan accordingly.

Teachers who attend workshops often walk away not knowing how to integrate lessons. Professional development offers little in the way of ongoing support for teachers following workshops. This weakness can easily be remedied with the inclusion of support and collaboration that is planned as follow up to the workshops. Another challenge is for teachers to

access more than a single workshop at a time. Workshops are often planned solely to learn and practice the technology. Usually there is some mention or discussion as to how teachers can use it in their classes, but the initial focus is inevitably on how to use it. In order to have time to attend workshops and have planned time to collaborate, the school administration must have money put aside to pay for replacement teachers so that teachers can pursue technology integration PD. If the intent is to use PLC time for collaboration and workshops, then it saves some money; however, it is easy for collaboration and plans to be pushed aside if other school matter arise that must be dealt with during PLC time.

Strengths. Workshops that are designed for beginner, intermediate and advanced pace either separately or together will likely have more participants able to learn at a pace best suited for them. The ideal, most cost-effective option is to create a workshop that is self-paced and guided through access to tutorials. This allows the instructor to be more of a facilitator providing an introduction and allowing participants to discover, learn the technology and ask questions as the progress through learning and using the technology. This also creates an atmosphere of collaboration and individualized learning, both methods that are also best for student learning. Teacher learning that takes place in the format that is best suited for students is ideal for teachers to experience individualized learning and understand how a collaborative environment can contribute to successful technology integration for learning. Workshops that occur in a series provide the opportunity for teachers to learn the technology with time to practice repeatedly building confidence and skills. A well-planned workshop that allows teachers to work and learn at their own pace while give teachers an even better understanding of the technology than if they were taught step by step.

How Teachers Learn Technology

Learning in a constructivist environment is a great way for teachers to learn how to learn technology. This is not an easy skill, especially for educators who lack confidence with technology. Participating in workshops that are offered in series with a focus on how to use technologies in the classroom will encourage teachers to explore their own lessons to see where they might be able to integrate technology for learning. This requires planning so that teachers can commit to all the workshops. Technology is best learned by experience and practice. Multiple opportunities to explore technologies allows teachers to really learn the technologies and more than that, become comfortable with making mistakes and fixing them in order to better understand how it works. Step-by-step tutorials are an excellent way for teachers to initially explore the capabilities of a technology. A second or third workshop, that follows, should be designed as an opportunity for teachers to develop a lesson, in collaboration with peers, that integrates the technology into their class. This allows teachers to build confidence with the technology and plan exactly how it can benefit students. During the lesson planning stage, it is important for the facilitator to point out the benefits of a constructivist classroom environment, as the participants are experiencing it in the session. Teachers need to play, plan and experience if they are to successfully integrate technology in their classes.

Skills that Teachers Need to Build

Teaching technology. There is no secret that the current generation of students in secondary school are 'digital natives'. This inevitably leads most adults, including teachers, to assume that our students are all quick learners when it comes to technology. In my experience, yes, many students are more apt with the use of technology, but more so with their personal devices and social media. When it comes to using tools for school, they too need to be guided in

the basics of using the technology, so it is essential that teachers know the technology well enough to explain the basics to students and be able to troubleshoot some common issues with the technology. Teachers should always introduce the technology as though students have no prior knowledge, this ensures that all students receive the same information. Similarly, to teachers, students each will learn the technology at their own pace. Prior to using it for learning purposes, teachers should provide students with time to explore and fiddle around with the technology, this will ensure they are comfortable with the basic functionality prior to completing their lesson or project.

Integrating technology. The technology integration must occur in stages, just as teacher PD should. Although students might require fewer stages than teachers might, going at a slower pace also allows the teacher to reflect on individual lessons and make adjustments as required. A single lesson planned for using the technology over one or two classes is a great way to see how students learn with the technology. A teacher who has taught the subject before will be able to formatively assess student learning and compare it to how students had learned without the use of technology. Following technology integration, teachers should, in collaboration, reflect on the success of the integration, identifying successes, challenges and any troubleshooting that was required during the lesson. This enables teachers to improve prior to implementing another lesson with the same class(es). Although there are a multitude of technologies that exist for education purposes, I will outline a few that are beneficial for all subject areas, and some that are specific for secondary science courses, beyond the digital whiteboard and classroom teacher computer.

Technology for secondary classes. There are basic technologies that are beneficial for all teachers to use for their classes during class and outside of class time. Google classroom

provides teachers a simple to set up page where they can post assignments, and students can submit them for grading. Teachers can also use this as a place to post resources, homework and answer keys for homework for students to access at their leisure. Teachers can archive old classes and create new ones while still reusing previous posts and assignments. Google and Weebly are just two of many options for teachers to create websites from templates. As opposed to a Google classroom, websites are to be set up more for the long term rather than re-created each term for each course. A website is an excellent place for teachers to provide the digital textbook, class notes, a calendar of important dates, and most importantly additional resources for learning. This is essential in order for teachers to develop a constructivist classroom. Rather than being guardians of knowledge, teachers can ensure that students have access to all the content, so that more class time can be spent on student led learning opportunities. There are also a variety of Web 2.0 tools that may be integrated into the classroom for learning.

Technology for secondary science classes. Further to the technology listed above, science has access to technology that can improve student understanding in science. A few different companies create digital probeware allowing students to quickly and effectively collect lab data such as pH and temperature of a chemical substance or the velocity of a moving object. Digital microscopes allow teachers to show enlarged images of their specimens. Virtual labs allow students to perform dissections they may be uncomfortable doing in class, or chemistry experiments with chemicals that are not permitted in schools. These technologies all provide opportunities for teachers to engage students further, to gain a deeper understanding, to connect more with the content so long as the learning is student led and motivates them to learn.

Action Plan

In this section I will outline a one-year PD plan to guide teachers through learning the technology, adjusting their pedagogy for technology integration. The ideal candidates for this plan are teachers who teach high school sciences, are comfortable with the content but have difficulty integrating technology in the classroom. I have provided, in Figure 1, intended goals and type of PD required on a monthly basis for the duration of the school year in order for teachers to see success with their technology integration.

Professional development plan for technology integration for secondary science teachers

Month	Format	Goals
September	<ul style="list-style-type: none"> ○ 2 Half day Workshops 	<ul style="list-style-type: none"> ✓ Build a digital classroom and online access to resources. ✓ Discuss goals for technology integration
October	<ul style="list-style-type: none"> ○ Collaboration time ○ Integration of digital classroom 	<ul style="list-style-type: none"> ✓ Practice assigning an assignment through the digital classroom with a peer. ✓ Create assignment for students to submit digitally
November	<ul style="list-style-type: none"> ○ Workshop ○ Integration technology using set lesson plan 	<ul style="list-style-type: none"> ✓ Learn a new technology to be used in class (probeware/digital microscopes/virtual labs) – depending on discipline being taught. ✓ Teacher is provided with a set lesson plan utilizing the technology.
December	<ul style="list-style-type: none"> ○ Collaboration time 	<ul style="list-style-type: none"> ✓ Collaboration meeting to reflect on lesson plan successes and challenges ✓ Develop another student led lesson using the same or similar technology.
January	<ul style="list-style-type: none"> ○ Implementation ○ Collaboration Time 	<ul style="list-style-type: none"> ✓ Implement lesson in class. ✓ Collaboration meeting to follow up on lesson.
February	<ul style="list-style-type: none"> ○ Workshop ○ Collaboration time 	<ul style="list-style-type: none"> ✓ Learn a new technology ✓ Develop a lesson plan to integrate it
March	<ul style="list-style-type: none"> ○ Collaboration time ○ Practice for new tech 	<ul style="list-style-type: none"> ✓ Follow up on lesson plan ✓ Develop a new lesson with same or new technology
April	<ul style="list-style-type: none"> ○ Collaboration time 	<ul style="list-style-type: none"> ✓ Follow up on lesson plan ✓ Develop multi day assignment/project that incorporates one or more technologies

May	○ Collaboration time	<ul style="list-style-type: none"> ✓ Follow up on lesson plan ✓ Develop online practice tests/questions using forms (Google/Microsoft/Survey Monkey)
June	○ Collaboration time	<ul style="list-style-type: none"> ✓ Follow up on review questions format, results. ✓ Create a list of technology integration goals for each course for the following year.

Figure 9 One year PD Plan.

This plan assumes that the administration has approved the cost of replacement teachers when necessary and has allotted time during the month for these teachers to build their technology skills and integrate it. The teachers following this plan would have a designated technology coach, available in the school to support them through the workshops, collaboration time and integration as required.

Rationale. It is important to note that lessons should be student led and collaborative. Creating a constructivist classroom structure for these lessons is how teachers can experience this type of learning. By experiencing it, teachers learn to manage the environment when integrating technology, ideally driving their understanding of its benefits. This structure allows for teachers to have opportunities to practice, learn and discuss multiple different technologies, however the layout may need additional workshops or increased collaboration time depending on the goals of the teachers and the challenges that may present themselves. Allowing flexibility in the schedule and the understanding that teachers may need to spend some independent time playing with the technologies might be required. Setting up digital access to resources is the beginning, and a simple way for teachers to begin letting go of control.

Teacher resources online. A teacher online resources center would be made available for teachers access for tutorials on various types of technologies, lesson plans that are ready to use for technology integration, a space for online teacher collaboration and a calendar of all pertinent dates as shown in Figure 2.



Figure 10 Image capture of the main page of my Google Site for teachers to access resources.

As the technology coach at my school, I have created a Google site that includes tutorials for various applications created either by me or by the Edmonton Catholic School District’s Emerging Technology Consultants. A sample of the tutorials accessible to teachers may be viewed in Figures 3, 4 and 5.

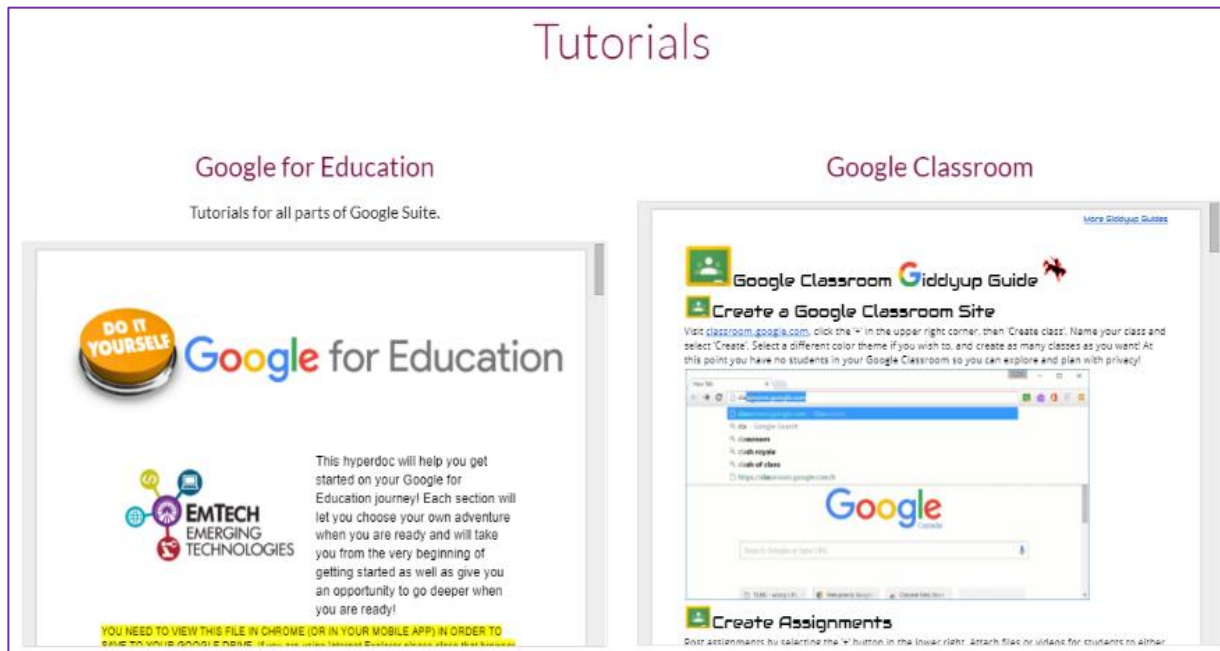


Figure 11 Tutorials for various Google applications and specifically Google Classroom.

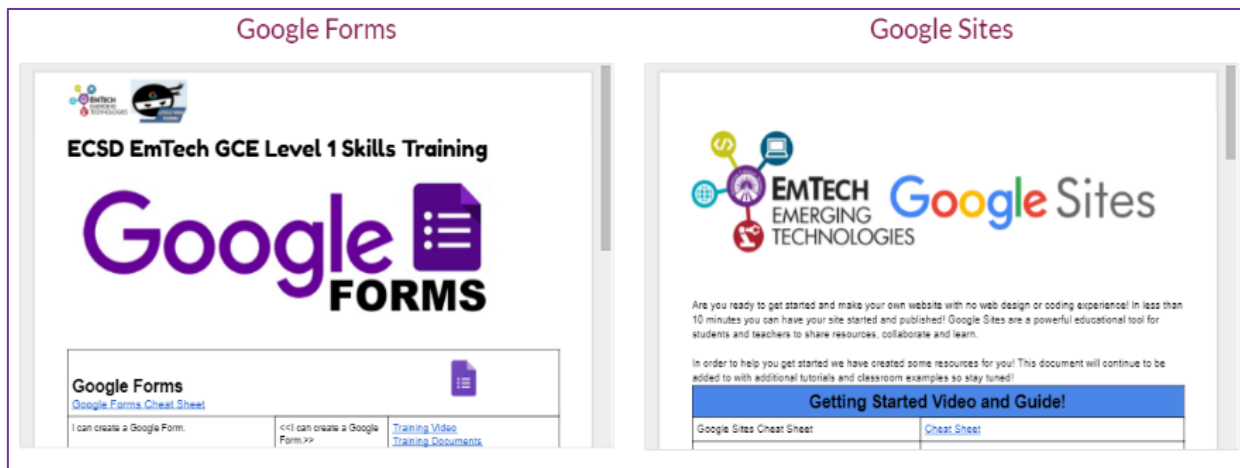


Figure 12 Tutorials for Google Forms and Google Sites

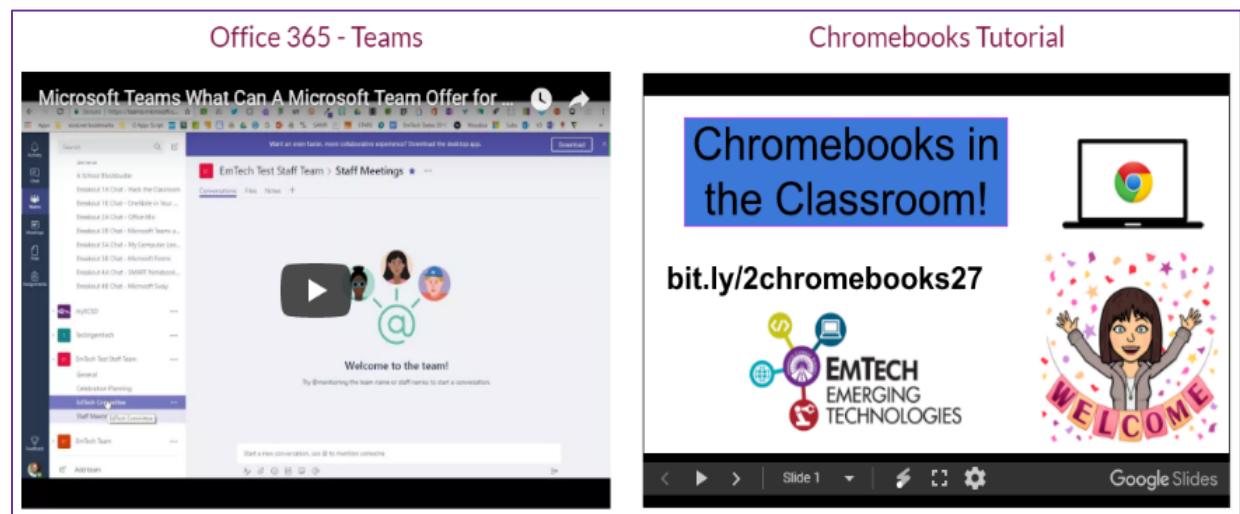


Figure 13 Tutorials for using Microsoft Teams and Chromebooks

This site also acts as an example for teachers of how their online site or classroom might look, and how convenient it is to access answers to questions without always having to go to the coach or facilitator. A Google classroom for teachers involved in the technology integration PD allows them to practice as a student, so they understand how to post, how to submit assignments so they can guide students appropriately. Google classroom, as seen in Figure 6, is laid out in a stream for announcements and posts.

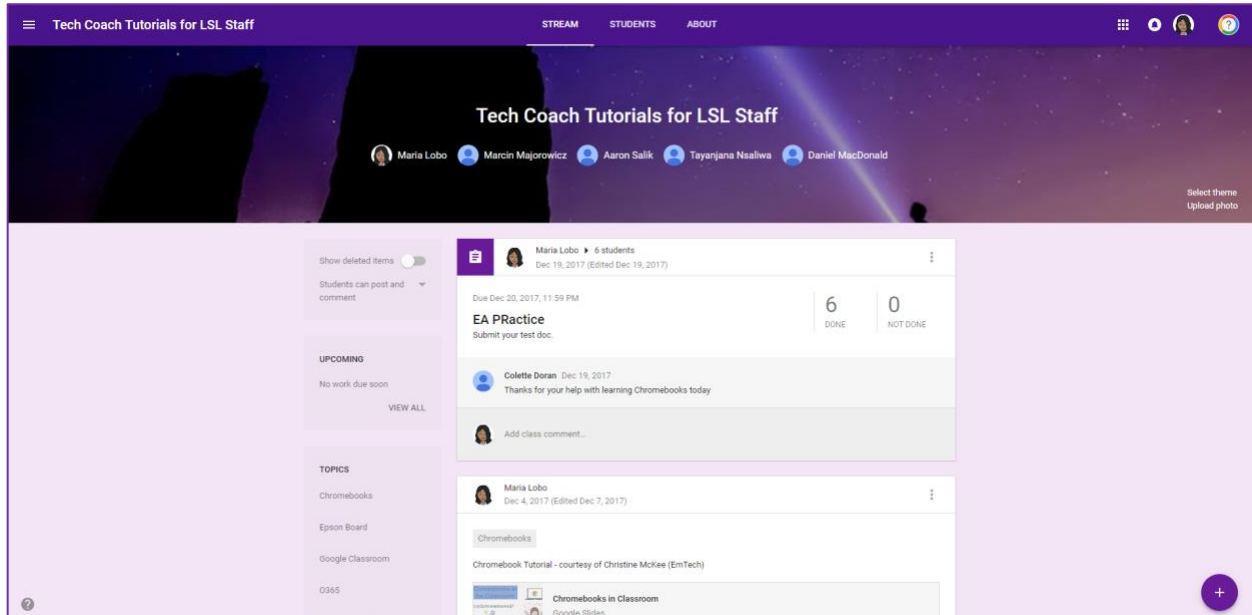


Figure 14 Sample Google Classroom set up for teacher discussion and practice.

This also acts as a place for teacher discussion. The reason I would stick with Google classroom as a place for discussion is that it limits the locations that teachers have to access to find information and access resources. Alternatively, forums can be created through Google Groups or Microsoft Teams and be embedded within the site for ongoing discussion. This allows teachers to explore and work at their own pace between workshops and collaboration meetings. Teacher collaboration should be created as a discussion forum so that teachers from different schools can ask questions and provide answers for each other, even if they are collaborating with teachers on site. If teachers are interested in using twitter to access resources, the site will provide hashtags and other educators to follow who are regularly tweeting about technology in classrooms as seen in Figure 7. There are often educational technology chats that are scheduled, that are beneficial for teachers to follow along or read later for more information. In the future, I intend to embed the discussion within the webpage for easier communication.

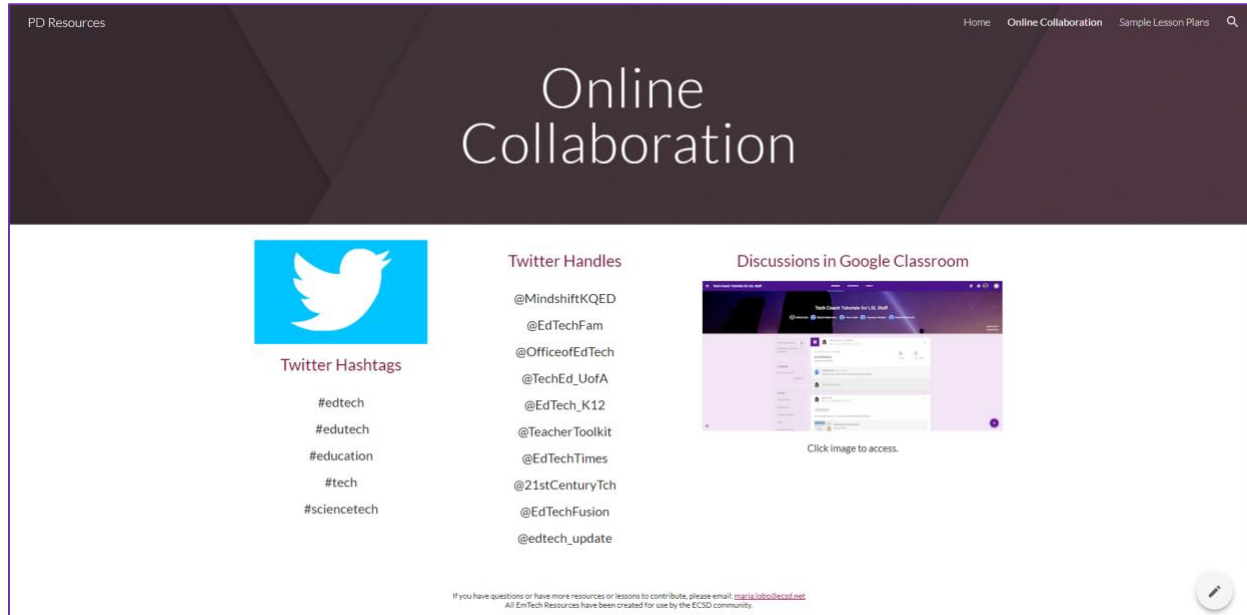


Figure 15 Page within the website that provides links to twitter and to a discussion for only those teachers involved in the PD.

Digital citizenship & literacy. Through this process, the coach should initiate some discussion and training regarding digital citizenship with teachers and also with students. Part of learning new technologies is understanding appropriate and inappropriate behaviours. It is therefore essential that teachers are somewhat digital and media literate, so they can appropriately manage any potential issues. Digital and media literacy is an important part of developing 21st century skills, skills that are best developed in a constructivist learning environment. Developing lessons that integrate technology in stages allows teachers to gauge how students use the technology so that issues can be remedied on an ongoing basis if integration occurs in stages. The website includes some literature and training for teachers to learn more about digital citizenship. This is especially important if teachers are looking to access social media and other Web 2.0 tools that are not managed by the district.

The screenshot shows a website interface for 'Digital Citizenship'. At the top, there is a navigation bar with 'PD Resources' on the left and 'Home', 'Online Collaboration', 'Sample Lesson Plans', and 'Digital Citizenship' on the right. The main heading is 'Digital Citizenship' in a large white font on a dark purple background. Below this, the text reads 'Resources for Teachers for teaching Digital Citizenship, Literacy and Safety on the Web'. Two links are provided: '[Digital Literacy Framework Website](#)' and '[Digital Citizenship and Safety Course](#)'. In the center, there is a video player thumbnail for a video titled 'Avoiding the Perils and Leveraging the Possibilities of Classroom Technology' by Danny Maas. The video thumbnail shows a computer screen with icons for Google Drive, OneDrive, Microsoft Teams, and Digital Portfolios. The video is part of the 'Teach Digital Citizenship' series.

Figure 16 Digital Citizenship and Literacy information for Teachers

Lesson plans. As part of the PD plan, lesson plans are provided for the teachers, so they can begin integrating technology following a cookie cutter lab or activity. This reduces the chance for error as it will have been tried before. The lessons will be provided on the website on their own page for teachers to access if they feel the need to try a few opportunities of technology integration prior to working on their own lesson. It is important to note that the sample labs would include teacher set up and notes as well as student instructions. There would be direction for classroom layout, if required, in order for teachers to get a feel for a constructivist learning environment.

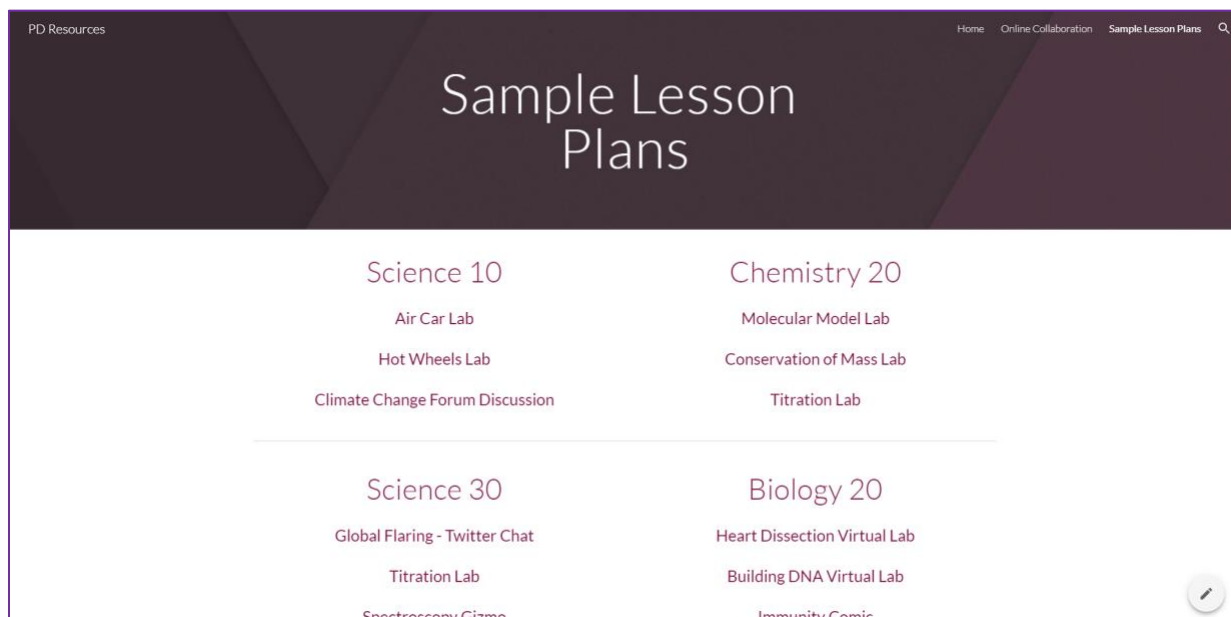


Figure 17 Prepared lessons for each high school science course are available for teachers to use.

A slow, paced process for integration also allows teachers to assess student learning with using the technology to determine if certain uses are more valuable than others. This plan is only a single school year designed to introduce teachers to technologies and allow them to experience technology for learning. The intent is to make teachers more comfortable with learning new technologies and understanding how best to integrate them into the classroom. Ideally, this method will motivate teachers and build their confidence to use technology more often to enhance learning. I do not believe that teachers will be experts after a single year, I do believe that if teachers are to be fully capable of learning new technologies on their own and building lessons with their peer, it is a two to three-year process depending on the teacher's initial technology skills and attitude.

Further research. Using an outlined plan such as I have listed, may become part of a study to determine if this progression would in fact see more teachers through the process to successful technology integration. Data would be collected through discussions during the

reflective collaboration sessions and from online forums. For further detail, the researcher may have individual discussions and provide questionnaires for teachers to answer; however, it is essential that this is completed during school time and replacement teachers are provided as well. I do believe this study extends beyond some of the studies I reviewed in the literature as this allows teachers to explore various technologies within their professional development rather than focusing on single types of technologies. This would promote learning and integration of technology in the classroom, furthermore it would focus more on building confidence in teachers, revising their pedagogy so they learn how to learn new technologies over time.

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