Technology integration in K-12 science classrooms: An analysis of barriers and implications

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Abstract. This paper examines the barriers to technology integration for Manitoban K-12 inservice science educators (n = 430) based on a 10-item online survey; results are analyzed according to teaching stream using the Technology, Pedagogy, and Content Knowledge (TPACK) framework. Quantitative descriptive statistics indicated that the leading barriers experienced by all teachers are inadequate: access; time; resources; training; budget; and support. Upon further examination, Middle Years and Senior Years teachers are considerably more likely to report that access and time hinder technology integration than their Early Years counterparts. Nearly 80% of all teachers remarked that technology was available to them, but about one quarter of respondents expressed frustration about the barriers that hinder effective technology integration in their classrooms. Implications of this study inform school division teacher support programs and planning, inservice professional development opportunities, and preservice teacher education.

Keywords: Science Education, Teaching and Learning, Technology Integration, Barriers; K-12 Classrooms

Introduction

The climate of Canadian science education in provincial and national contexts points to a poignant need to address and improve science teaching and learning in Manitoba. Looking with a macro lens, Canadian Programme for International Student Assessment (PISA) scores in science in 2009 ranked seventh in the world, however, Manitoba science scores are well-under Canadian averages. Evidenced by the Pan-Canadian Assessment Program (PCAP) 2010 scores, Manitoban students lag significantly behind their fellow provincial counterparts. In light of the upcoming 2013 PCAPs testing with a major focus on science, government agendas have turned to provincial action plans for the inclusion of technology integration and 21st century skills (Luu & Freeman, 2011).

The inclusion of technological skills in science education is one means the provincial government's educational body, Manitoba Education, hopes will address student engagement and conceptual understanding of science in Manitoba (Manitoba Education, n.d.). Active engagement in science, as Seimears et al. (2012) contend, is a primary goal of science education reform. "In general, teachers share a value belief that technology improved student motivation and engagement" (Ottenbreit-Leftwich et al., 2010, p. 1328). As such, technology integration has become a widely popular trend (Tsai & Chai, 2012) and go-to 'fix' for the ails of educational woes, as well as a major focus for granting agencies, such as the Canadian Social Sciences and Humanities Research Council (SSHRC), in their priority areas of digital economy (SSHRC, 2012). In so much as technology integration may improve teaching and learning in science, teachers experience a range of barriers to effectively integrate technologies into their pedagogical practices.

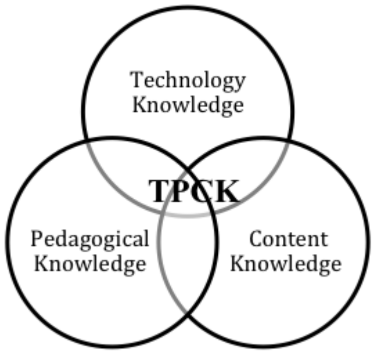

Figure 1. TPACK model (Mishra and Kohler, 2006)

As such, this study is timely and of critical importance. Examining the challenges that science teachers encounter when integrating technology into their teaching and learning processes will better help schools, school divisions, superintendents, and curriculum consultants to understand and support their teachers. This study adds a current Canadian perspective to the international knowledge generated by Graham et al. (2009); Hakverdi-Can & Dana (2012); Hechter, Phyfe & Vermette (2012); Hechter & Vermette (2012); Jimoyinannis (2010); Lin et al. (2012); Metcalf & Tinker (2004); Niess (2005); Penuel & Fishman (2012); Varma, Husic & Linn (2008); and Windschitl (2009) who have each examined technology-integration practices, specifically within science education. While this area of study has received some attention in past years, we acknowledge technology-integration as a growing area of importance in current pedagogical practices, and as such, our study is particularly significant given the relatively few authors currently publishing studies about technology integration in science classrooms. Further, as technology integration is broadly used across a variety of teaching disciplines, at all age levels, the results of this study are transferrable to other educational settings.

Theoretical Framework

Acknowledging the work of Mishra and Koehler (2006), we recognize technology as a key component of the theoretical underpinnings of the TPACK framework, as well as a current trend in Manitoban classrooms. The TPACK framework (Figure 1) highlights the relationship between technological knowledge, pedagogical knowledge and content specific knowledge (in our case, science); portraying these knowledge bases as three interlocking circles functioning as a collaborative and interactive theoretical structure within classroom teaching and learning. The oscillating overlap of these knowledge bases (Hechter et al., 2012), provides a desired intersection for effective technology integration in K-12 classrooms.

These ideas are not entirely novel, as Niess (2005), discussed the major components of teaching with technology, pedagogy, and content before the development of the TPACK framework (Mishra & Koehler, 2006). Regardless, TPACK has been widely accepted in the educational community as the theoretical model grounding the desired implementation of effective technological practices. However, as 'curriculum designers' in their own classrooms (Mishra & Koehler, 2007), findings suggest that factors such as teachers' knowledge bases (Mishra & Koehler, 2007), and teachers' beliefs (Ertmer, 2005; Ertmer et al., 2012) affect teachers' pedagogical decisions and classroom practices. Thus, if teachers are to be agents of change in their own classrooms (Mishra & Koehler, 2007), they may be better able to effectively match technologies to appropriate lessons by understanding and applying the principles of TPACK. It stands to reason then that technology integration issues, to certain extents, “can be resolved if teachers possess stronger TPACK capacity” (Tsai & Chai, 2012, p. 157). As the gap between espoused and enacted beliefs of teachers diminishes (Ertmer et al., 2012), and barriers are removed (Ertmer, 1999; Ertmer et al., 2012; Hew & Brush, 2007; Ottenbreit-Leftwich et al., 2010; Wachira & Keengwe, 2011), logic suggests that effective technology integration in classroom teaching and learning will increase.

While intuitively correct, this assumption does not recognize the intricacies of science teaching and learning; the complex language of the TPACK model; nor the context of science education in Manitoba. Graham et al. (2009) identified that classroom teachers need more support to link content-specific technologies to science in meaningful ways. In addition, Graham (2011) discussed the theoretical jargon of the TPACK framework, urging for further clarification on term definitions within the framework to aid accessibility for classroom practitioners. Finally, the context and climate of science education in the province of Manitoba is diverse; covering great expanses of land, there are ‘have’ and ‘have-not’ regions of Manitoba. In these diverse rural and urban settings, teachers meet the needs of their students through rich and varied technological access, at times, or the complete lack thereof, at others. For some areas of Manitoba, school divisions are installing wireless broadband internet towers and fibre optics networks to increase bandwidth at incredible upfront costs, keeping their teachers on the cutting edge of access to technology. For other areas of Manitoba, internet access is only available through dial-up phone connections, if at all; leaving teachers’ abilities to integrate certain technologies limited as much by geography and infrastructure, as by other factors.

Literature Review

Barriers to technology integration

How then has the analysis and examination of barriers to technology integration changed over time? Ertmer (1999) identified both external and internal barriers to integrating technology, finding that external barriers (referred to as first-order barriers by Ertmer (1999) are access to technology, time, training, and support (p. 56); whereas internal barriers (second-order barriers) are teachers’ fundamental beliefs about “teacher-student roles, curricular emphases, and assessment practices” (Ertmer, 1999, p. 58). Becker (2000) found technology was a valuable tool in schools and classrooms where teachers have access to technology are prepared to use it, have some freedom in the curriculum, and hold personal philosophical beliefs aligned with student-centered, constructivist pedagogies (p. 25).

Constructivist pedagogies in science are lifelong, active constructions of knowledge that students conceive and use to interpret or predict events in their experiential worlds (Seimears et al., 2012, p. 266). Facilitated by the teacher as a guide, rather than through the means of direct instruction, these pedagogies are seen as beneficial in science; allowing students to experience and interact with scientific content and phenomena through questioning, examining, engaging, exploring, and developing new insights (Seimears et al., 2012, p. 270). In relation to technology integration in science, constructivist pedagogies encourage hands-on interaction with science-based technologies, allowing students to construct relevant and meaningful understandings of science phenomena. With the strong push towards constructivist, student-centered pedagogies touted as best teaching practices (Harris, 2005), it is no wonder that teachers are less likely to report pedagogical beliefs that contrast these working ideals as barriers in their own pedagogical practices (Ertmer et al., 2001; Hechter & Vermette, 2012; Judson, 2006; Ottenbreit et al., 2010).

Pelgrum (2001) conducted a study about the integration practices of samplings of schools in 26 countries around the world; discussed the obstacles inherent to the integration of Information Communications Technology (ICT) in education; and found that common challenges to technology integration were insufficient numbers of computers to adequately integrate technology into teaching and learning (p. 174); that teachers lacked knowledge/skills to integrate technology (p. 174); and that there were not enough computers with simultaneous access to the world wide web (www) (p. 174) to effectively integrate technology in classrooms. Hew and Brush (2007) shed light on this issue by creating an extensive list of 123 barriers that seemed to prevent successful integration of technology into classrooms based on an extensive literature review. They organized their findings in terms of six major groupings, namely: resources; knowledge and skills; institution; attitudes and beliefs; assessment; and subject culture (Hew & Brush, 2007, p.226).

Metcalf and Tinker (2004) provided insight as to the feasibility aspects of integrating technology into classrooms based on the considerations of costs, teacher professional development, and instructional design. Ertmer (2005) examined how teacher pedagogical beliefs influence barriers to technology integration, finding that teachers' pedagogical beliefs are a major factor in the integration of technology into classroom teaching and learning. Gado, Ferguson and Van'T Hooft (2006) indicated further causes that may inhibit classroom technology integration, including classroom and school environments that do not support technology integration, teachers' lacking technological backgrounds and predispositions, students' lacking prior knowledge and experience, the lack of an open and engaging curriculum that incorporates technology, and lack of access to handheld computers as learning tools. Inadequate training becomes another barrier, as articulated by Hughes (2008) in a discussion on how teachers need to learn to teach technology to students; and in the research by Jones, Bennett and Lockyer (2009) on the challenges in the design process for teaching technology integration in courses.

Current barriers to technology integration

Following up on the work of Ertmer (2005) about teacher beliefs as perhaps the largest determining factor of technology integration in classrooms, Ottenbreit-Leftwich et al. (2010) studied the value beliefs of teacher uses of technology and, acknowledging the findings of Hew and Brush (2007), Ottenbreit-Leftwich et al. (2010, p. 1322) remarked that there are many barriers that prevent effective technology integration that have been supported in extant literature, including lack of time and resources, school culture, teacher abilities, and teacher beliefs (Ertmer, 1999; Ertmer, 2005; Hew & Brush, 2007). Ertmer et al., (2012) analyzed the relationship between teachers' beliefs and technology integration practices finding that teachers' whose attitudes and beliefs support technology integration, and who had the knowledge and skills to carry out their beliefs, were more likely to experience success regardless of the barriers they face (p. 423). Tsai and Chai (2012) suggested that there exists a crucial third-order barrier to technology integration in classrooms, namely design thinking by teachers (p. 1059). Design thinking is a teacher's ability to "create learning materials and activities, adapting to the instructional needs for different contexts or varying groups of learners" (Tsai & Chai, 2012, p. 1058). These authors found that even when a "teacher has sufficient facility, rich digital instructional resources, positive attitudes or strong beliefs toward technology integration, he/she may not have successful implementation" (Tsai & Chai, 2012, p. 1058) because students and classrooms are dynamic. This aligns with the work of Harris (2005) who, in an attempt to promote educational reform by technology integration, found that it was more beneficial to respect the pedagogical plurality of teachers' academic freedoms, which encompasses "many different digitally supported instructional strategies while trusting our colleagues to consider and choose appropriately among all of them" (Harris, 2005, p. 121).

Wachira and Keengwe (2011) found that while access to computer technology in schools is improving, consistent declines in both use and integration of computer technology for the enhancement of student learning were apparent for the teachers that they surveyed (p. 17). This finding is admittedly disappointing, as the budgets and expenditures from Manitoban school divisions for technology integration in school teaching and learning continue to grow. "Rather than expecting technology to change the nature of teaching and learning, it may be more beneficial to help teachers use technology to enhance the curriculum in ways they see fit" (Ottenbreit et al, 2010, p. 1323). Perhaps then, it is with this goal, that teacher support programs will promote teachers and learners to "use appropriate curriculum-based technological applications more pervasively in all of their varied forms" (Harris, 2005, p. 121). This ideal is perhaps not fully shared by Ottenbreit et al., (2010) who suggested that while this was a positive initial starting place, a goal is to "consider how to move these teachers toward student-centered practices once their competence and confidence increases with these initial uses" (Ottenbreit et al., 2010, p. 1332). Hughes (2005) and Ottenbreit-Leftwich et al. (2010) suggested that "any new technology use should target a specific purpose that aligns with teachers' value beliefs associated with teaching and learning in their own classrooms" (Ottenbreit et al., 2010, p. 1332). However, while many of these barriers reflect teacher challenges, few mention how this new generation of school-aged children is impacted by effective integration of technology in the classroom.

21st Century students

Students populating our classrooms during the past decade view and use technology differently than previous generations. This current generation of technology multi-taskers might be called "screenagers" (Buffin, 2007; Rushkoff, 1996), since the boundaries of what media they use, and what they use it for, are now blurred. Youth of today continue to exacerbate this trend as they access a multitude of screens in their daily lives (whether using phones, computer monitors, or televisions), in order to communicate, gather, and share information. Reaching students with digital fluency requires integrating technology into the science classroom to engage them in meaningful and relevant ways that connect with their daily lives. Becker (2000) found that technology integration is more successful when teachers' pedagogies align with collaborative projects that spark student interest (p. 25). Respondents in the study by Ottenbreit-Leftwich et al. (2010) reported "technology creates learning situations in which students use the unique capabilities of instructional technology to learn in ways they could not achieve without the use of technology" (p. 1328).

Technology integration in schools

Hew and Brush (2007) define technology integration "as the use of computing devices such as desktop computers, laptops, handheld computers, software, or Internet in K-12 schools for instructional purposes" (p. 225). We take these definitions one-step further, distinguishing between instructional technologies and educational technologies (Earle, 2002). Instructional technologies are technologies placed largely in teachers' hands for the purposes of presenting and sharing information and lessons (Hechter & Vermette, 2012); and that educational technologies, similar to the definition of Hew and Brush (2007), are the technologies that students engage with to improve the quality of student learning in science, such as handheld technologies, sensors, and Ipads, to name a few (Hechter & Vermette, 2012).

TPACK in Science Education

Literature suggests that significant, effective student learning takes place when integrating technology within the science classroom (Metcalf & Tinker, 2004; Reid-Griffin & Carter, 2004; Vonderwall, Sparrow & Zachariah, 2005; Zucker et al., 2008). The National Research Council (2006) supports the integration of technology in scientific inquiry as a powerful learning tool, and purports that those tools may contribute to the enhancement of student understanding of key scientific concepts (Adams & Shrum, 1990; Laws, 1997; Nicholau et al., 2007; Roblyner, 2000; Settlage, 1995). Further, recent advanced studies linking TPACK directly to science knowledge frameworks (Jimoyinannis, 2010), reflective science teacher perceptions of the TPACK framework (Lin et al., 2012), and theoretical positions of the model (Hechter et al., 2012) are new and different research lines that will continue to inform this area of academic knowledge that relates the TPACK model and science education.

Research Study

Research Question

The aim of this research is to determine what types of barriers Manitoba science teachers experience when integrating technology into their science teaching and learning. Guiding questions for this paper are: 1) How are barriers experienced by teachers' instructing in different streams (Early Years, K-4; Middle Years, 5-8; Senior Years, 9-12; or Multiple Streams)?; 2) Are there common barriers across all streams?; and, 3) Are there barriers that are unique to specific streams?

Method

With the aim of developing a better understanding of the challenges and barriers that teachers experience when integrating technology into their science classrooms, our study obtained research ethics approval to survey Manitoban teachers. Invitations to an online survey housed in Survey Monkey containing 10-technology integration related items were sent to school division superintendents across Manitoba. Superintendents were asked to disseminate the invitation to schools within their divisions, specifically addressed to science teachers. To participate, teachers needed to be currently teaching any level of K-12 science, or to have taught science within the previous two school years.

Participants

Out of the 505 teachers who opened the survey, 433 Manitoban K-12 science educators completed it, a response rate of 85.74%. Participants were located in both urban and rural schools settings, and in both private and public schools. This study focused on K-12 science education, and as such, the sample for this study consists solely of inservice teachers within this teaching range who volunteered to participate. The K-12 teaching range was selected because technology is being purchased to be broadly integrated across all grade levels in Manitoba (Table 1), and it was therefore deemed appropriate to survey a sampling of teachers at all levels. Data was collected on behalf of 22 participating Manitoban school divisions, and 16 Manitoban independent schools. Teachers reported having an average of 21-22 students in each of their science classrooms, with smallest class sizes being one-three students and largest being 35-36 students. Teacher demographics ranged across all years of teaching experience and with differing confidence levels for integrating technology into their classroom teaching and learning.

Table 1. Grade levels taught by survey respondents

What grade level(s) do you teach?	Frequency	Percent
Early Years K-4	130	30.0
Middle Years 5-8	130	30.0
Senior Years 9-12	118	27.3
Multiple Streams	55	12.7
Total	433	100.0

Survey Instrument and Procedures for Analyzing Data

Email invitations to participate were distributed to Manitoban science teachers via their administrators and superintendents. Written informed consent, outlining the rights and responsibilities of both researchers and volunteer participants, was obtained prior to the demographic, LIKERT-type, and open-ended questions. The 10-item questionnaire was administered through Survey Monkey, an online survey program, where data was received and compiled. Qualitative responses were gathered, compared, and grouped through grounded theory approaches (Creswell, 1998). Quantitative statistical analysis of the numerical data in the form of frequency tables was generated through Survey Monkey and SPSS. For the purposes of this paper, we focus only on the questions regarding the barriers that teachers experience when integrating technology into their classroom practices and delineating those responses according to teaching stream.

Reliability and Validity

To ensure reliability and lower the margin of error, the 15-20 minute survey contains clear language, appropriate formatting for readability, and was available in online format for just over three months. Volunteer participation and demographic questions lead to a diversity of participants across public and private schools, across all years of teaching experience, and different grade levels throughout K-12. Participants were able to select their time and location to complete the survey, helping to ensure anonymity.

Aggregate data was compiled from open-ended survey questions, and thus contains some degree of researcher subjectivity and bias as to the categorization of responses. However, each researcher independently reviewed data, and results remained consistent between each researcher's findings from the sample. Results may be skewed slightly in favour of teachers who already feel comfortable using technology, due to the online format of the survey. The question about 'factors that prevent technology integration in the classroom' was an open-ended question allowing for a variety of responses. Had it been posed as a check-list or LIKERT-type question, it is possible the percentages of responses may have been significantly higher.

Demographic questions about ethnicity, socio-economic status or race of the teachers, students, or the communities in which they teach are not asked. Nor are questions asked about teachers' age, gender, rural/urban teaching experience, public/independent school teaching experience, educational background, or number of years of science teaching experience. Those areas of diversity were not within the scope of this survey, but will be addressed in future studies.

Results and Discussion

Consistent with first-order barriers to change in technology integration as reported by Ertmer (1999), our 2011 study yielded surprisingly similar results (Table 2). Why are access, time, lack of resources, training, budget constraints, and inadequate teacher support processes still the leading barriers to technology integration in Manitoban K-12 science classrooms, while in the United States many of these key barriers were being overcome by school divisions by 2005 in place of teachers' pedagogical beliefs as a final challenge (Ertmer, 2005)? It could be that Tsai and Chai (2012) are correct in that it is teachers' design thinking, as a third-order barrier that is hindering teacher usage of technology. Or perhaps, in Manitoba, for a variety of reasons including geography and financial constraints, it is still a feasibility issue for school divisions who struggle to diminish these barriers for teachers.

Out of the 433 teachers who completed the survey, 430 answered the following question: Are there factors (ie. lack of available resources, limited budget) that prevent you from integrating technology into your science classroom? If so, please explain below. If not, please write, "There are no discernible factors preventing me from integrating modern technology into my science classroom" in the space below. Their responses are provided in the following table. Independent responses (IR), as well as grouped responses (GR) by theme, are provided in the table below.

Regardless, nearly 80% of teachers, when asked "Are there factors (i.e. lack of available resources, limited budget) that prevent you from integrating technology into your science classroom?", responded by saying that technology was available to them (Table 3) , but there were many factors preventing them from using it effectively, or at all. This has resulted in teacher frustrations as reported by nearly one quarter of all respondents (Table 4).

Table 2. Barriers to Technology Integration in the Science Classroom

Teacher Responses	Early Years Stream K-4 (n = 128)	Middle Years Stream 5-8 (n = 129)	Senior Years Stream 9-12 (n = 118)	Teaching in Multiple Streams (n = 55)	Totals (n = 430)
Access (GR)	62 (48.4%)	103(79.8%)	91 (77.1%)	32 (58.2%)	288 (67.0%)
Time (GR)	63 (49.2%)	77 (59.7%)	83 (70.3%)	14 (25.5%)	237 (55.1%)
Lack of Resources (IR)	68 (53.1%)	77 (59.7%)	57 (48.3%)	29 (52.7%)	231 (53.7%)
Training (GR)	74 (57.8%)	60 (46.5%)	58 (49.2%)	24 (43.6%)	223 (51.9%)
Budget Restrictions (IR)	30 (23.4%)	47 (36.4%)	61 (51.7%)	25 (45.5%)	163 (37.9%)
Support (GR)	23 (18.0%)	38 (29.5%)	25 (21.2%)	9 (16.4%)	95 (22.1%)
No Preventing Factors (IR)	21 (16.4%)	14 (10.9%)	12 (10.2%)	12 (21.8%)	59 (13.7%)
School and classroom demographics and priorities (IR)	7 (5.5%)	12 (9.3%)	11 (9.3%)	13 (23.6%)	43 (10.0%)
Need age and language appropriate resources	14 (10.9%)	12 (9.3%)	11 (9.3%)	1 (1.8%)	38 (8.8%)
Teaching Preference/ Not Best Teaching Practice (GR)	6 (4.7%)	4 (3.2%)	12 (10.2%)	2 (3.6%)	24 (5.6%)
Students' Age (IR)	10 (7.8%)	4 (3.1%)	1 (0.8%)	0 (0.0%)	15 (3.5%)
Lack of Science Equipment (IR)	2 (1.6%)	2 (1.6%)	9 (7.6%)	2 (3.6%)	15 (3.5%)

Table 3. Teachers who said that technology is available to them in schools within their open-ended responses about factors that affect their technology integration

	Early Years K-4 (n = 128)	Middle Years 5-8 (n = 129)	Senior Years 9-12 (n = 118)	Multiple Streams (n = 55)	Totals (n = 430)
Technology Available in Schools	76 (59.4%)	122 (94.6%)	104 (88.1%)	36 (65.5%)	338 (78.6%)

Table 4. Teachers who said that they feel frustrated with barriers that hinders their use of technology in their science teaching and learning

	Early Years K-4 (n = 128)	Middle Years 5-8 (n = 129)	Senior Years 9-12 (n = 118)	Multiple Streams (n = 55)	Totals (n = 430)
Teacher Frustrations	24 (18.8%)	31 (24.0%)	23 (19.5%)	6 (10.9%)	106 (24.7%)

Approximately 95% of Middle Years teachers (n = 129) and nearly 90% of Senior Years teachers (n = 118) said that technology was available, while only about 60% of Early Years teachers (n = 128) said that this was the case. As an open-ended question, the responses ranged significantly between participants, and yet, considerably less Early Years teachers responded in this way. Does this speak to a lack of technological access or awareness for Early Years teachers? Is it a lack of support for technology integration in Early Years classrooms? Or simply that many Early Years teachers did not choose to respond about availability when answering an open-ended question about barriers to technology integration? It is impossible to know right now, but it serves as a good starting point for future research.

We group the factors that impede technology integration within classroom pedagogical practices into four areas, namely: administrative, technological, organizational, and philosophical barriers to technology integration. Administrative barriers include access, time, and teacher support. Technological barriers are training, and teachers' knowledge, awareness, skills, and mentorship opportunities. Organizational barriers include lack of resources and budget, lack of science equipment, students' ages, and school/classroom demographics and priorities. Philosophical barriers are teachers' pedagogical decisions about best teaching practices and interests.

Administrative Barriers

Access

Access to technology is the leading barrier to technology integration in Manitoban K-12 science classrooms, as 67% of teachers acknowledged that this was an issue for them (Table 5). Higher percentages of teachers in the Middle Years and Senior Years Streams (79.8% and 77.1%, respectively) reported this as an issue, while 58.2% of Multiple Stream teachers, and only 48.4% of Early Years teachers mentioned this. Key aspects to access as a barrier to technology integration, as reported by Manitoban science teachers were that technology was not accessible at reasonable times; there was not enough for the class; there were restrictions on using certain technologies, programs, and websites; and that teachers lacked choice in the technology they use. Similar to the findings of Pelgrum (2001), where insufficient numbers of computers and lack of computers with access to the world wide web were significant issues; it is wonderful that schools in Manitoba have technology available, but if it is not accessible to teachers when they need it for their lessons, what really is its value? It seems that Manitoba, as a whole, is only now beginning to support teachers towards effective integration of technology in science education, but elsewhere in the world, this area is moving much faster in this direction. However, increasing technology availability and access is a step in the right direction that coupled with targeted professional development that deconstructs the tenets of the TPACK model can make a positive difference in the technology integration landscape in Manitoba.

Time

Time is another critical factor of inservice K-12 science teachers in Manitoba for their quest to integrate technology into their classroom teaching and learning (Table 6). Over 55% of teachers reported that time was an issue in some capacity within their pedagogical practices. Common time barriers included time for teachers to learn to use the technology; time to plan technology integration, as well as research and develop appropriate resources to use with their class; time needed to teach heavy and demanding curriculums; and time for students to learn the technologies. These results are consistent with first-order barriers to technology integration as recognized by Ertmer (1999). Senior Years teachers are slightly more likely to report time as an issue than their Middle Years and Early Years counterparts. Surprisingly, this result may have been anticipated with the factor of time 'needed to teach heavy and demanding curriculums', but was not reported to be a greater obstacle for Senior Years teachers in this area.

Support

Approximately 22% of teachers found school/divisional support for technology integration to be a factor (Table 7). A first-order barrier recognized by Ertmer (1999); within our study, support includes a sentiment from teachers that technologies are always breaking down; that adequate IT support is not readily available; that there is not enough space to set it up or use it properly; that some programs do not work, do what they are designed for, or stall; and finally, that while technology is available, technology remains unused because it takes a significant length of time to install it once it has arrived.

Table 5. Access

Item	Early Years K-4 (n = 128)	Middle Years 5-8 (n = 129)	Senior Years 9-12 (n = 118)	Teaching in Multiple Streams (n = 55)	Totals (n = 430)
Not accessible at reasonable times	25 (19.5%)	41 (31.8%)	32 (27.1%)	12 (21.8%)	110 (25.6%)
Not enough for my class	20 (15.6%)	27 (20.9%)	25 (21.2%)	8 (14.5%)	80 (18.6%)
Teachers lack choice in the technology they use	14 (10.9%)	15 (11.6%)	21 (17.8%)	4 (7.3%)	54 (12.6%)
Restrictions on using certain technologies, programs, and websites	3 (2.3%)	20 (15.5%)	13 (11.0%)	8 (14.5%)	44 (10.2%)
Totals for access by stream	62 (48.4%)	103 (79.8%)	91 (77.1%)	32 (58.2%)	288 (67.0%)

Table 6. Time

Item	Early Years K-4 (n = 128)	Middle Years 5-8 (n = 129)	Senior Years 9-12 (n = 118)	Teaching in Multiple Streams (n = 55)	Totals (n = 430)
Time, in general	25 (19.5%)	31 (24.0%)	36 (30.5%)	5 (9.1%)	97 (22.6%)
Time for teachers to learn the technologies	15 (11.7%)	15 (11.6%)	18 (15.3%)	4 (7.3%)	52 (12.1%)
Time to plan technology use; research and develop appropriate resources	14 (10.9%)	15 (11.6%)	18 (15.3%)	4 (7.3%)	51 (11.9%)
Time needed to teach the curriculum	4 (3.1%)	9 (7.0%)	7 (5.9%)	1 (1.8%)	21 (4.9%)
Time for students to learn the technologies	5 (3.9%)	7 (5.4%)	4 (3.4%)	0 (0.0%)	16 (3.7%)
Totals for time as a barrier by stream	63 (49.2%)	77 (59.7%)	83 (70.3%)	14 (25.5%)	237 (55.1%)

Table 7. Support

Item	Early Years K-4 (n = 128)	Middle Years 5-8 (n = 129)	Senior Years 9-12 (n = 118)	Teaching in Multiple Streams (n = 55)	Totals (n = 430)
Always breaking down	5 (3.9%)	10 (7.8%)	8 (6.8%)	2 (3.6%)	25 (5.8%)
Inadequate IT support	5 (3.9%)	7 (5.4%)	7 (5.9%)	4 (7.3%)	23 (5.3%)
Not enough space to set it up/ use it properly	6 (4.7%)	12 (9.3%)	3 (2.5%)	1 (1.8%)	22 (5.1%)
Programs do not work, do not do what they are designed for, or stall	4 (3.1%)	6 (4.7%)	5 (4.2%)	1 (1.8%)	16 (3.7%)
Slow technology installations	3 (2.3%)	3 (2.3%)	2 (1.7%)	1 (1.8%)	9 (2.1%)
Totals for support by stream	23 (18.0%)	38 (29.5%)	25 (21.2%)	9 (16.4%)	95 (22.1%)

Technological Barriers

Training

A first-order barrier to technology integration by Ertmer (1999), training was also a major limiting factor for technology integration in our survey findings (Table 8). Just over 50% of teachers in our survey reported a lack of training as a major hurdle in the effective integration of educational technologies. Teachers reported that professional development was sorely needed to train teachers to use technologies; to train teachers to integrate technologies effectively in the science classroom; and, to improve teacher knowledge bases, experience with technologies, awareness of technologies, and comfort in applying those technologies in classroom settings. In addition, but to a lesser extent, teachers also requested mentor teachers to guide them on practical technological integration in science on a regular basis, or at very least a Information Technology (IT) specialist available in their schools to provide daily support.

Table 8. Training

Item	Early Years K-4 (n = 128)	Middle Years 5-8 (n = 129)	Senior Years 9-12 (n = 118)	Teaching in Multiple Streams (n = 55)	Totals (n = 430)
Professional development needed to train teachers to use technologies	32 (25.0%)	24 (18.6%)	33 (28.0%)	12 (21.8%)	101 (23.5%)
Teacher knowledge, experience, awareness, and comfort	26 (20.3%)	21 (16.3%)	14 (11.9%)	7 (12.7%)	68 (15.8%)
Professional development needed to train teachers to integrate technologies in science	16 (12.5%)	15 (11.6%)	11 (9.3%)	5 (9.1%)	47 (10.9%)
Totals for training by stream	74 (57.8%)	60 (46.5%)	58 (49.2%)	24 (43.6%)	216 (50.2%)

Organizational Barriers

Lack of resources and budget restrictions

Lack of resources was reported as a factor prohibiting technology integration in Manitoba K-12 science classrooms by approximately 54% of teacher respondents. In the literature review of 48 empirical studies by Hew and Brush (2007), lack of resources was a major factor impeding technology integration in the majority of studies. The percentages for lack of resources as a reported barrier are fairly comparable and consistent barrier across all teaching streams.

School and classroom demographics and priorities

An interesting area reported by 10% of teachers is that the demographics of the classrooms, schools, and communities can, at times, be a limiting factor to technology integration for teachers. While technology and internet connectivity is limited in some areas of Manitoba due to geography, in other areas it is limited by choice. This has to do with school, divisional and community priorities, which vary by school and division and may be affected by factors such as 'at-risk' status of students; origins and beliefs of community members and leaders; and divisional priority agendas such as literacy and numeracy education. Perhaps not as surprising, findings also indicate that teachers who concurrently teach in multiple streams are considerably more like to report this as a factor than teachers in individual streams. We speculate that this may be because teachers' who teach in multiple streams, tend also to be educating students in small schools, more often rural or independent in nature, or in specialized classrooms with specialized agendas. Recognizing that we cannot determine that this is the case, due to the nature of the demographic questions that we have asked, we will have to explore this area in future research or leave it as just that, speculation.

Age and language

A number of teachers (8.8%) reported that they wished that age and language appropriate resources were available to them, and an additional 3.5% of teachers reported that students' age was a factor in teachers' ability to integrate technology into their classroom pedagogical practices. Skewed slightly in favour of Early Years, ten teachers reported that teaching children in the K-4 age category was limiting due to the age of students, the need for one on one support to integrate technologies with young students, and the lack of technological experience and expertise by educational support staff. Of the teachers that reported that knowing where and how to acquire language appropriate technology-based resources was a limiting factor, the overwhelming response was that French resources were either unavailable, or teachers were unsure how to locate technology-based resources in the French language. This is an understandable factor for our K-12 science teachers, as Manitoba is part of a region where Francophone and French Immersion schools exist.

Lack of science equipment

An additional 3.5% of teachers reported that a lack of science equipment in general was a barrier to integrating technology in their classrooms. This sentiment had much to do with not wanting to spend what little budget was available on technology in lieu of restocking necessary laboratory supplies to perform necessary classroom experiments and investigations. Other teachers reported that digital microscopes and digital cameras were not available, or that budgets were limited and spread thinly for supplies among large numbers of teachers and students.

Philosophical Barriers

Teaching preference

On the surface it may appear a disappointing result that science teachers reported 5.6% of the time that incorporating technology into science teaching and learning was not best teaching practice or not an interest of the teacher (Table 9). While these were the reported results, it may not be simply because they do not value technology itself, but rather that they value something else more. Some teachers reported that teaching technology with a hands-on interactive approach was not possible with technology, while others reported that they use technology to provide a hands-on approach to science with their students. Even though some teachers reported that technology was not used in their classroom because it did not interest them personally, it is the feelings of these researchers that this may only be part of the story. Why some teachers feel that technology can be a factor preventing effective teaching and learning, while others do not, is interesting and requires further investigation. Is it the technologies themselves that these teachers are trying to integrate that are not useful? Or perhaps teachers are having difficulties matching specific technologies to appropriate science lessons? Perhaps they possess both the science equipment and a supportive administration, allowing for the use of varied experiments and labs within their classroom already, and do not require online simulations to teach these skills. Whatever the reason, this area can be further explored in future studies.

No Preventing Factors

Nearly 14% of teachers reported that there were no factors that prevent integration of technology in their classrooms. This data is particularly interesting when it is compared with teacher confidence levels, actual pedagogical practices in the use of educational technologies, in the types of technologies used, and in whether or not the technology used in these classrooms is teacher or student directed. Unfortunately, due to the trajectory of this paper, this area will need to be explored in future research and other papers.

Table 9. Teaching preference

Item	Early Years K-4 (n = 128)	Middle Years 5-8 (n = 129)	Senior Years 9-12 (n = 118)	Teaching in Multiple Streams (n = 55)	Totals (n = 430)
Feel it is not best teaching practice	5 (3.9%)	2 (1.6%)	8 (6.8%)	2 (3.6%)	17 (4.0%)
Not an interest of the teacher	1 (0.8%)	2 (1.6%)	4 (3.4%)	0 (0.0%)	7 (1.6%)
Totals for teaching preference by stream	6 (4.7%)	4 (3.2%)	12 (10.2%)	2 (3.6%)	24 (5.6%)

Implications and Future Research

As technologies like SMARTboards, hand-held probeware, digital cameras, and e-tablets are being purchased for inclusion into the science teaching and learning, we cannot help but wonder if the financial and educational focus on technology integration is in fact making a positive difference in terms of the quality of science teaching and learning across Manitoba. How do researchers, teachers and administrators know if the technology is being integrated effectively? Targeted professional development focused on sharing and mobilizing knowledge through professional learning communities that seek to answer such questions through workshop events and outreach projects, is a suggested starting place. Professional learning community projects that provide the space to facilitate multi-directional flow of relevant and timely information between academic researchers, and the larger community of practicing professionals, policy makers, and representatives of schools and school divisions across the province of Manitoba will support these conversations to take place. Ottenbreit-Leftwich et al., (2010) found that "professional development programs are likely to be more effective if they demonstrate technology uses that align with teachers' value beliefs" (p. 1330), therefore professional development series should link the teachers' values to anticipated technology-enriched outcomes.

Overcoming Barriers to Technology Integration in Classrooms

Tsai and Chai (2012, p. 1059) posit that "the enhancement of design thinking for teachers is not a major component of teacher education programs", but they feel it should be, as it represents the third-order barrier to technology integration in classrooms. Teachers who understand design thinking with technology "can undertake technology integration actively and fluently" (Tsai & Chai, 2012, p.1059), thereby using "technology for instruction at the right time and right place" (Tsai & Chai, 2012, p. 1059) within their pedagogical practices. "Barriers will always exist in one form or another" according to Tsai and Chai (2012, p. 1059). Hew and Brush (2007) described the strategies to overcome barriers as: "(a) having a shared vision and technology integration plan, (b) overcoming the scarcity of resources, (c) changing attitudes and beliefs, (d) conducting professional development, and (e) reconsidering assessments" (p. 233). But resolving, "first order barriers is more than purchasing and possessing hardware and software" (Tsai & Chai, 2012, p. 1058).

For teachers, in particular, believing that technology integration in science is important is simply not enough. It is having the acquired skills and abilities to act upon their beliefs that is essential and can otherwise prove to be one of the most substantial barriers (Ertmer et al., 2012; Graham et al., 2009; Windschitl, 2009). Teachers "with the knowledge, skills, abilities, dispositions, creativity, and desire to integrate technology into classroom teaching and learning encounter barriers... employ their innovative and critical problem-solving abilities to structure lessons with technological variety using what is at hand, and what can be obtained or accessed" (Hechter et al., 2012, p. 138; Hakverdi-Can & Dana, 2012; Hew & Brush, 2007; Wachira & Keengwe, 2011). Teaching pedagogy that involves technology integration effort "can be reinforced through engaging teachers in teaching belief transformation, improvement in teaching performance, and professional learning" (Shieh, 2012, p. 213). According to Penuel and Fishman (2012), "enduring partnerships between research and practice" (p. 297), such that are developed in the professional learning communities and targeted professional development series, are critical for sustained, substantive school reform and professional development (p.297) and should include a network of "researchers, practitioners, curriculum and program developers, and public and private investors with a stake in improving educational systems" (Penuel & Fishman, 2012, p. 297).

Conclusions

Our survey, focusing on the nature and extent of technology integration in science classrooms across Manitoba, brought to light two main findings. First, school divisions and administrators are heavily investing in technologies intended to transform classrooms to fit within the digital age. Second, classroom teachers are unclear on effective ways to integrate these technologies into their teaching and have a low comfort level with their personal knowledge and use of these new technologies. Many other studies support these findings (Levin & Wadmany, 2008; Russell et al., 2007). Varna et al. (2008) further suggest that even when teachers introduce technology into the classroom, they often use this technology ineffectively due to their own lack of technological literacy.

This study adds to the limited literature on viewing science education through the lens of the TPACK framework. As applying TPACK to science content is underrepresented in the current literature, an exploration of the interrelatedness of technology integration, pedagogical practices, and science content is sorely needed. Building on the international works of Hakverdi-Can and Dana (2012), Jimoyinannis (2010), and Lin et al. (2012), our study provides a fresh, Canadian perspective on technology-integration in science teaching and learning. Reaching across grade levels, our research addresses the barriers that teachers encounter when integrating technology into their pedagogical practices in a way that can be transferrable to science educators nationally and internationally, as well as across other teaching disciplines in a variety of settings.

As a direct result of this study, we have developed a professional development workshop series for both inservice and preservice teachers. This year-long series is predicated on overcoming the general and specific barriers to technology integration, while encouraging teacher participants to be critical reflective practitioners in regards to why, and how, they are currently integrating modern technology into their science teaching and student learning.

Manitoban K-12 science classrooms are still working to overcome first-order barriers to technology integration such as access, time, lack of resources, training, budget constraints, and inadequate teacher support processes. Administrative, technological, organizational, and philosophical barriers exist that seriously hinder the effective implementation of technology into classroom teaching and learning. While teacher beliefs may be the leading factor hindering positive technology integration in schools (Ertmer, 2005), Manitoba appears to lag behind in improving first-order barriers, and has yet to begin addressing second-order barriers in many educational contexts. Targeted professional development opportunities for preservice and inservice teachers that hold teachers' value beliefs in high regard; respect teachers' unique perspectives; help teachers develop design thinking skills; and create professional learning communities; are suggested first steps in striving to overcome barriers to effective technology integration in Manitoban K-12 science classrooms, thereby helping teachers hone their craft of integrating technology into their classroom for improved teaching and learning of science.

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