Exploring the use of web-based learning tools in secondary school classrooms

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This study explored the impact of Web-Based Learning Tools (WBLTs), also known as learning objects, in secondary school mathematics and science classrooms. Surveys, open-ended questions, and student performance data were collected from a sample of 8 teachers and 333 students. Teachers rated the learning benefits, quality, and engagement value of WBLTs very high. Students rated these same features moderately high. Student performance with respect to remembering, understanding, applying, and analyzing concepts increased significantly (28–53%) when WBLTs were used. Qualitative data suggested that a number of students reacted positively to the following qualities of WBLTs: visual supports, learning benefits, ease of use, animations, graphics, and engagement. Some students were concerned about pace (too fast), challenge level (too hard), and the quality of help features when using WBLTs. Overall, it appears that the WBLTs used in this study had a positive impact on teacher and student attitudes, as well as student learning performance.

Keywords: evaluate; assess; quality; scale; effect; middle school; WBLT; web-based learning tools; online learning tools

Overview

The majority of today's secondary students have been raised on a steady diet of technology and Internet access (Montgomery, 2009; Palfrey & Gasser, 2008; Tapscott, 2008). Outside the classroom, this so called "net-generation" instinctively turns to the web to communicate, find information, learn, and perform personally relevant tasks (Tapscott, 2008). Inside the classroom, the use and impact of technology and the web appears to be marginal at best. A number of researchers have reported that computer technology has had a minor or negative impact on student learning (e.g. Collins & Halverson, 2009; Cuban, 2001; Koehler & Mishra, 2008; Roberston, 2003; Russell, Bebell, O'Dwyer, & O'Connor, 2003; Williamson & Redish, 2009). Part of the problem stems from a considerable list of obstacles that have prevented successful implementation of technology (Collins & Halverson, 2009; Eifler, Greene, & Carroll, 2001; Strudler, Archambault, Bendixen, Anderson, & Weiss, 2003; Thompson, Schmidt, & Davis, 2003; Wepner, Ziomek, & Tao, 2003).

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It is argued that web-based learning tools (WBLTs), also know as learning objects, offer key features that address potential obstacles and enhance student learning. The purpose of this study was to explore the impact of WBLTs in secondary school mathematics and science classrooms.

Literature review

Definition of WBLTs

WBLTs are defined in this article as "interactive web-based tools that support learning by enhancing, amplifying, and guiding the cognitive processes of learners". This definition was composed from an amalgamation of previous efforts to define learning objects (Agostinho, Bennett, Lockyer, & Harper, 2004; Butson, 2003; McGreal, 2004; Parrish, 2004; Wiley et al., 2004). The term "web-based learning tool" is used in this study instead of "learning object" because the label clearly reflects the intent of the proposed definition. In essence, we are talking about *tools* that students and teachers access from the *web* to support *learning*.

Practical benefits of WBLTs

A number of persistent obstacles have prevented teachers from embracing and using technology effectively in secondary school classrooms including limited time to learn new software (Eifler et al., 2001; Wepner et al., 2003), inadequate computer-based skills (Eifler et al., 2001; Strudler et al., 2003; Thompson et al., 2003), fear of technology (Bullock, 2004; Doering, Hughes, & Huffman, 2003), not understanding how to integrate technology into teaching (Cuban, 2001), and insufficient access to software and hardware (e.g. Bartlett, 2002; Brush et al., 2003; Russell et al., 2003). WBLTs provide a number of practical benefits that directly address these obstacles.

A typical WBLT is designed to focus on a single concept and is very easy to use (e.g. Kay & Knaack, 2008a, 2008c, 2009a, 2009b; Sedig & Liang, 2006). Because WBLTs are user-friendly, the time and skills required by teachers and students to learn how to use them is negligible. Ease of use also has the potential to minimize fears associated with using computers (e.g. Kay & Knaack, 2008a, 2008c, 2009a, 2009b). Additionally, WBLTs are typically free of charge and readily accessible on the Internet. Furthermore, a number of good quality WBLTs offer teaching materials and integration strategies. Finally, since high speed access to the web is available in a majority of schools in many countries (e.g. Compton & Harwood, 2003; McRobbie, Ginns, & Stein, 2000; Plante & Beattie, 2004; Tapscott, 2008) teachers and students have a wide range of WBLTs from which to choose.

Learning benefits of WBLTs

Many WBLTs are designed to support exploration, investigation, construction of solutions, and manipulation of parameters instead of memorizing and retaining a series of facts (Kay, 2009e; Kay & Knaack, 2008a, 2008c; Sedig & Liang, 2006). Focussing on deeper levels of understanding using a constructivist approach is well supported in cognitive science and brain-based literature (e.g. Bransford, Brown, & Cocking, 2000; Bruner, 1986; Kafai, 2006; Medina, 2008; Sousa, 2006; Vygotsky, 1978; Willingham, 2009). Also, a number of WBLTs provide visual supports that help make abstract concepts more easily understood (Kay & Knaack, 2008a, 2008c;

Sedig & Liang, 2006). Some WBLTs allow students to explore higher level concepts by reducing working memory and cognitive load (Sedig & Liang, 2006). In addition, two common characteristics of most WBLTs are clear learning goals and immediate feedback. These two conditions help increase motivation to learn (Barkley, 2010; Wlodkowski, 2008). Finally, WBLTs allow users to control the pace of learning environment thereby permitting a more palatable assimilation of new concepts. (Bransford et al., 2000; Kay & Knaack, 2008a, 2008c; Willingham, 2009).

In summary, a well-designed WBLT can help students focus on deeper learning, offer visual scaffolding, reduce cognitive load, motivate learning, and tender educational guidance at a pace that is controlled by the user.

WBLTs in secondary school

Research on the use of WBLTs in secondary schools is relatively new, with the majority of studies published after 2006. An extensive review of the literature revealed 10 peer-reviewed articles (Brush & Saye, 2001; Kay & Knaack, 2007, 2008a, 2008c, 2009a, 2009b; Lopez-Morteo & Lopez, 2007; Lowe et al., 2010; McCormick & Li, 2006; Schibeci et al., 2008). These articles have examined three areas of impact: teacher perspective, student perspective, and learning performance.

Teacher perspective

Seven studies looked at how teachers viewed WBLTs (Kay & Knaack, 2007, 2008a, 2008c, 2009a, 2009b; McCormick & Li, 2006; Schibeci et al., 2008). Kay and Knaack (2007, 2008a, 2008c, 2009a, 2009b) have repeatedly demonstrated that teachers believe that WBLTs are effective learning tools, easy to use, and engaging for students. They also note that teachers are typically more positive about the use of WBLTs than students. McCormick and Li (2006) reported that 60–75% of teachers thought WBLTs were enjoyable to use and helpful to students, although over 50% reported technical problems local to their schools. Finally, Schibeci et al. (2008) observed that teachers were very enthusiastic about WBLTs, noting that these tools stimulated new ways of viewing the curriculum.

Student perspective

Eight studies explored how students perceived the use of WBLTs (Brush & Saye, 2001; Kay & Knaack, 2007, 2008a, 2008c, 2009a; Lopez-Morteo & Lopez, 2007; McCormick & Li, 2006; Schibeci et al., 2008). Brush and Saye (2001) observed that students tended to look at superficial content in a WBLT when left to their own devices and that more active guidance and structure was needed when using information-based WBLTs. Kay and Knaack (2007, 2008a, 2008c, 2009a, 2009b) used a comprehensive assessment measure and reported that students were moderately positive about the learning, design, and engagement features of WBLTs. In addition, overall usefulness, clear instructions, an organized layout, and a good theme were particularly important. Lopez-Morteo and Lopez (2007) reported that students liked using interactive, recreation-based, collaborative WBLTs. Finally, Lowe et al. (2010) and Schibeci et al. (2008) noted that students thought WBLTs were easy to use, enjoyable, helpful with respect to providing useful visual supports,

and, to a lesser extent, engaging. It was also observed that students would avoid reading long passages of text.

Student performance

Kay and Knaack (2008a, 2008c, 2009a, 2009b) are the only researchers who looked at student learning performance as a result of using WBLTs in secondary school environments. The results indicated that student performance increased significantly, from 30 to 40%, particularly when science-based WBLTs were used (Kay & Knaack, 2008a, 2009a).

Methodological issues

While some very informative qualitative data have been provided in previous studies, there are a number of methodological problems that need to be addressed in order to improve the quality of future data on the use of WBLTs.

First, a clear description of the sample population including context, number of students, gender, grade level and/or subject taught was missing in several studies making it challenging to generalize any conclusions to a larger population (Lopez-Morteo & Lopez, 2007; Lowe et al., 2010; Schibeci et al., 2008). Second, when survey data were collected, reliability and validity estimates were often missing (Brush & Saye, 2001; Lopez-Morteo & Lopez, 2007; Lowe et al., 2010; McCormick & Li, 2006; Schibeci et al., 2008). Third, even though multiple sources of qualitative data were collected, the standard criteria for assessing the quality of data gathered including transparency, credibility, negative cases, triangulation, and rich description (Gay, Mills, & Airasian, 2009; McMillan & Schumacher, 2010; Miles & Huberman, 1994; Patton, 2002) were not presented (Brush & Saye, 2001; Lowe et al., 2010; McCormick & Li, 2006; Schibeci et al., 2008). Finally, the majority of studies examined the use of one or two WBLTs, thereby limiting the scope of the results reported.

It is worth noting that Kay and Knaack (2007, 2008a, 2008c, 2009a, 2009b) addressed most of the methodological concerns listed above. However, they did not control for several key variables in their studies including quality of WBLTs and lesson plans used, standardization of student performance measures, and range of cognitive skills assessed when WBLTs were used. The current study attempts to address each of these variables.

Purpose

The purpose of this study was to explore the impact of WBLTs in secondary school classrooms from the perspective of both teachers and students.

Method

Overview

The following steps were taken to ensure the quality and analysis of the data:

(1) a large, diverse, sample was used;
(2) reliable and valid surveys were employed;

(3) issues of transparency, credibility, and negative cases were addressed when analyzing the qualitative data;

(4) a wide range of high quality mathematics and science-based WBLTs were pre-selected based on the Kay and Knaack's (2008b) multi-component model for evaluating WBLTs;

(5) a set of pre-designed lesson plans were created based on previous research looking at effective strategies for using WBLTs; and

(6) an enhanced measure of student performance was included based on the revised Bloom taxonomy (Anderson & Krathwhol, 2001).

Sample

Students

The student sample comprised of 333 secondary school students (166 males, 166 females, 1 missing data), 15–17 years of age ($M = 15.1$, $SD = 0.35$). Almost 70% ($n = 230$) of the students reported an average mark 70% or more in the subject area in which the WBLT was used. About three-quarters of the students ($n = 243$) agreed or strongly agreed that that they were good at working with computers. In addition, 80% ($n = 294$) of the students noted that they liked working with computers at school. The sample population was gleaned from 17 different secondary school classes located within a sub-urban region of almost 600,000 people.

Teachers

The teacher sample consisted of eight secondary school instructors (two males, six females). Subject areas covered were science ($n = 15$ classes) and mathematics ($n = 2$ classes) in grades 9 ($n = 15$) and 10 ($n = 2$). Teaching experience ranged from 0.5 to 4 years with a mean of 2.1 ($SD = 1.42$). All teachers agreed that they were comfortable with and liked using computers at school. In terms of frequency of use, 75% of the teachers used computers with their classes once a month or less.

WBLTs and lesson plans

Four teachers were trained for two days on how to select WBLTs for the classroom and develop effective lesson plans. The criteria for selecting WBLTs were based on Kay and Knaack's (2008b) multi-component model for assessing WBLTs. The lesson plan design was evolved from the results of a previous research study by Kay, Knaack, and Muirhead (2009). The key components of these lesson plans included a guiding set of questions, a structured well-organized plan for using the WBLTs, and time to consolidate concepts learned. Over a period of 2 months, a database of 122 lesson plans and WBLTs was developed (78 for mathematics and 44 for science). A total of 12 different WBLTs were selected by teachers from the WBLT database. See Appendix A (Kay, 2010a) for a complete list of all WBLTs used by secondary school teachers in this study.

Procedure

Teachers from two boards of education were asked to volunteer to use WBLTs in their classrooms. Each teacher received a full day of training on using and

implementing the pre-designed WBLT lesson plans. They were then asked to use at least one WBLT in their classroom. Email support was available for the duration of the study. All students in a given teacher's class used the WBLT that the teacher selected, however, only those students with signed parental permission forms were permitted to fill in an anonymous, online survey. In addition, students completed pre- and post-tests based on the content of the WBLT. These tests were pre-designed by the authors of the lesson plans to match the learning goals of the specific WBLT used.

Data sources

Teacher survey

All instructors were asked to complete the WBLT Evaluation Scale for Teachers to assess their perceptions of how much students learned (learning construct), the quality of the WBLT (quality construct) and the degree to which students were engaged when using the WBLT (engagement construct). The three constructs selected were based on a detailed review of the literature (see Kay & Knaack, 2005, 2007). The scale showed fair to moderate reliability and good construct validity (Kay, Knaack, & Petrarca, 2009). Internal scale reliability estimates for the current study were 0.94 (perceived learning), 0.85 (quality of WBLT), and 0.85 (engagement). See Appendix B (Kay, 2010b) for a copy of the teacher survey.

Teacher comments

Three open-ended questions were used to collect qualitative data about (a) the overall impact that the WBLT had on learning, (b) technical issues experienced, and (c) advice for future teachers who might want to use WBLTs.

Student survey

After using a WBLT, students were asked fill in the WBLT Evaluation Scale for Students to assess their perceptions of how much they had learned (learning construct), the quality of the WBLT (quality construct), and how much they were engaged when using the WBLT (engagement construct). The constructs selected were based on a thorough review of the literature (Kay & Knaack, 2005, 2007, 2009a, 2009b). The scale showed good reliability, face validity, construct validity, convergent validity, and predictive validity (Kay & Knaack, 2009a, 2009b). Internal-reliability scale estimates in the current study were 0.94 (perceived learning), 0.87 (quality of WBLT), and 0.93 (engagement). See Appendix C (Kay, 2010c) for a copy of the scale used.

Student comments

Students were asked open-ended questions about what they liked and disliked about the WBLT. The responses were organized according to the coding scheme provided in Appendix D (Kay, 2010d). This coding scheme was used to categorize 532 student comments. Each comment was then rated on a 5-point Likert scale ($-2 =$ very

negative, -1 = negative, 0 = neutral, 1 = positive, 2 = very positive). Two raters assessed all comments made by students and initially achieved inter-rater reliability of 52% on the categories and 57% on the ratings. The two raters discussed differences in coding and independently re-rated the comments. The final inter-rater reliability was 98% for categories and 97% for numerical ratings.

Note that the total impact of any one category was determined by multiplying the mean rating by the total number of students who made a comment. For example, in Table 3, the total impact of visual supports on learning was calculated by multiplying the mean which was 1.05 by the number of students who commented about visual supports (39) for a total of 41.0.

Student performance

Students completed a pre-test and post-test based on the content of the WBLT used in class. These tests were included with all pre-designed lesson plans to match the learning goals of the WBLT. The difference between pre- and post-test scores was used to determine changes in student performance on four possible categories of questions: remembering, understanding, application, and analysis. These categories were derived from the revised Bloom's Taxonomy (Anderson & Krathwhol, 2001). The number of question types assessed varied according to the type of the WBLT used and the pre-designed tests.

Key questions and data analysis

To examine the impact of WBLTs on secondary school students, the following questions were targeted in the data analysis:

(1) How do teachers rate the learning, quality and engagement of WBLTs? (teacher survey)
(2) What are teacher comments with respect to overall impact, technological challenges, and advice to future teachers? (open-ended questions)
(3) How do students rate the learning, quality and engagement of WBLTs? (student survey)
(4) What do students like and dislike most about WBLTs? (open-ended questions)
(5) How do teacher ratings of WBLTs compare with student ratings? (correlation between teacher and student surveys)
(6) How do WBLTs affect student performance ? (t-test comparing pre- and post-scores)

Results

Lesson plan evaluation

The lesson plans used in this study were pre-designed in order to improve the quality of WBLT-based classes. It is important to evaluate how well these lessons were received by the teachers who used them. A majority of teachers (90–95%) agreed that the lesson plans were easy to follow, well designed, and matched their style of teaching, although 50% of the teachers made some changes.

Teacher rating of WBLTs

Learning

The mean rating for impact on learning (Items 8a to 8d – Appendix B in Kay, 2010b) was 25.3 ($SD = 2.6$) or an average of 6.4 on a 7-point scale. This high mean score, coupled with a narrow range (22–28) indicates that teachers agreed that the WBLT had a positive impact on student learning (Table 1).

Quality of WBLT

The mean rating of WBLT quality (Items 7a–7c – Appendix B in Kay, 2010b) was 18.5 ($SD = 1.5$) or an average of 6.2 on a 7-point scale. Again the range of scores was relatively narrow (15–21). Teachers in this study thought the WBLTs were of good quality (Table 1).

Engagement

Teachers rated engagement of WBLTs (Items 9a–9d – Appendix B in Kay, 2010b) with a mean score of 24.6 ($SD = 3.1$) or an average of 6.2 on a 7-point scale. While the range of scores was a bit broader (18 to 28), it is clear that most teachers agreed that the WBLTs were engaging for students (Table 1).

Teacher comments – overall impact

The majority of teachers comments (16 out of 24) regarding impact of WBLTs focussed on learning. WBLTs were thought to be effective for reviewing previous knowledge, helping with procedural knowledge, providing real world examples, supporting understanding of concepts, and providing visual aids. Sample comments were:

> This [WBLT] allowed students to interact with the visualization software to test their previous knowledge
> The [WBLT] helped ... clarify the steps in solving the word problem.
> Students definitely understood the concept [better] than other years I have taught it without the use of a [WBLT].
> The [WBLT] helped to visualize the problem

Other comments referred to student enjoyment. Samples comments were:

> Students really enjoyed the [WBLT].
> Students enjoyed the videos associated with the different sections.

Table 1.   Teacher ratings of learning, quality, and engagement for WBLTs ($n = 17$).

Scale	No. items	Possible range	Actual range observed	Mean (SD)
Learn	4	4–28	21–28	25.3 (2.4)
Quality	3	3–21	15–21	18.5 (1.6)
Engagement	4	4–28	18–28	25.6 (3.3)

Teacher comments – technology problems

Teachers from 8 of the 17 classes who used WBLTs reported no technology problems. Minor issues that did occur included one computer that could not be connected to the Internet (hardware), two labs where it was a challenge to run java-based programs on some computers (software), and three WBLTs where slight accuracy problems were noted. Overall, no significant problems inhibited students from using WBLTs.

Teacher comments – advice for future teachers

Three themes emerged with respect to advice to future teachers planning to use WBLTs. The first theme was to test the WBLT and practice ahead of time (three teachers). The second theme was to not expect the WBLT to teach concepts by itself – adequate support has to be given to students before and during the use of WBLTs (three teachers). The final theme was that if a lab was not available, the WBLT could also be effective as a demonstration tool in front of the class.

Student ratings of WBLTs

Learning

Students rated WBLTs lower than teachers with respect to learning (Items 8a–8f – Appendix C in Kay, 2010c) ($M = 31.6$, $SD = 6.5$) with a mean item rating of 5.3 out of 7. This means that students, on average, ''slightly agreed'' that WBLTs helped them learn. The broad range of scores (6–42) indicates that there was considerable variability with respect to student attitudes about the learning benefits of WBLTs (Table 2).

Quality of WBLTs

Students rated the quality of WBLTs (Items 7a–7d – Appendix C in Kay, 2010c) higher than the learning value ($M = 22.1$, $SD = 4.0$), although the mean item rating (5.5 out of 7) was still lower than that of the teachers. Again, the range of scores (4–28) showed considerable variability in opinions about the quality of WBLTs used (Table 2).

Engagement

Student ratings of WBLT engagement (Items 9a to 9d – Appendix B in Kay, 2009c) were moderate ($M = 20.3$, $SD = 5.0$) with a mean item rating of 5.1 out of 7,

Table 2. Student ratings of learning, quality, and engagement for WBLTs ($n = 333$).

Scale	No. items	Possible range	Actual range observed	Mean (SD)
Learn	6	6–42	6–42	31.6 (6.5)
Quality	4	4–28	6–28	22.1 (4.0)
Engagement	4	4–28	4–28	20.3 (5.0)

indicating that students, on average, ''slightly agreed'' that the WBLT they used was engaging. High variability among student engagement ratings is indicated by the wide range of scores reported (4–28).

Student comments about WBLTs

Over 450 student comments are summarized in Table 3. A detailed set of examples for each category of student comments is available in Appendix E (see Kay, 2010e). Regarding overall, general comments, students appeared to have a favorable attitude toward WBLTs with positive comments outnumbering negative comments by a factor of 2:1. With respect to learning, visual supports and overall learning were the highest rated categories, whereas pace of learning and pedagogical challenge were rated the lowest. Some students felt rushed ($n = 8$) when using the WBLT, while other students thought the WBLT they used was confusing and hard to follow ($n = 26$).

With respect to rating the quality of WBLTs, ease of use was the highest rated feature, followed by the visual components (animations and graphics). Students were divided on whether they liked the degree of interactivity, overall design, and theme. Some students felt to there was too much text to read ($n = 8$) or that the help features were not effective ($n = 12$)

Regarding engagement, a number of students appeared to enjoy using computers better than other teaching methods (compare category), thought that WBLTs were

Table 3.   Summary of student comments about WBLTs.

Category	Mean	SD	Total	Total negative	Total positive	Total effect mean × n
General						
General/overview	0.38	1.37	34	10	21	13.0
Learning						
Visual supports	1.05	0.46	39	1	38	41.0
Overall learning	0.57	1.06	42	11	31	24.0
Pace	−1.11	0.60	9	8	0	−10.0
Challenging	−0.71	1.06	34	26	7	−24.0
Quality						
Easy to use	0.97	0.39	33	1	32	32.0
Animation	0.67	0.92	24	5	19	16.0
Graphics	0.38	1.08	42	12	30	16.0
Interactive	0.29	1.08	28	10	8	8.0
Org/design	0.08	1.26	13	7	6	1.0
Control	0.00	1.15	4	2	2	0.0
Theme	−0.10	1.20	10	6	4	−1.0
Audio	−1.00	0.00	2	2	0	−2.0
Text	−1.13	0.35	8	8	0	−9.0
Help	−1.08	0.76	13	12	1	−14.0
Engagement						
Compare	0.77	0.71	26	2	23	20.0
Engage	0.37	1.31	51	19	32	19.0
Technology	0.44	0.97	27	7	20	12.0
Strategy						
Teaching approach	−0.91	1.04	11	9	2	−10.0

Table 4. Pre-post test score differences.

Question type	Pre-test mean (%)	Post-test mean (%)	% change	n	t	Effect size
Remembering	27.4 (30.5)	66.6 (40.0)	39.2	243	-14.6^*	1.10
Understanding	11.0 (41.3)	64.2 (61.1)	53.2	122	-15.1^*	1.02
Application	21.7 (23.6)	49.7 (26.0)	28.0	119	-10.8^*	1.13
Analysis	21.6 (38.0)	67.1 (44.1)	45.5	67	-7.7^*	1.11
Total score	26.6 (24.3)	64.2 (25.9)	37.6	282	-22.3^*	1.50

Note: $^*p < 0.001$.

engaging, and liked using computers. A smaller number of students reported that they were not engaged while using the WBLT ($n = 19$).

Finally, a small group of students ($n = 9$) did not like the teaching strategy used with the WBLT. While there was no clear pattern, concerns included difficult to follow handouts, the teacher showing students how to use the program instead of letting students learn it themselves, and having to do too much writing.

Student performance

Five-paired tests were conducted to assess differences between pre- and post-test scores on four categories of questions (remembering, understanding, application, and analysis) and the total test score. The WBLTs used in this study appeared to focus on remembering most, followed by understanding and application. Analysis questions were asked least often.

Theoretically, a MANOVA may be a better statistical procedure to use when assessing differences with multiple dependent variables; however, not all question categories were asked for each WBLT. Therefore, the MANOVA eliminated considerable data and it was decided that using multiple t-tests was a better procedure to follow. All four question categories showed significant increases in test scores (Table 4). Increases in scores ranged from 28 to 53% resulting in large effect sizes based on Cohens's d (Thalheimer & Cook, 2002).

It is worth noting that a student's average grade, comfort level with the subject area being taught, self-rated ability to use computers, and liking to use computers were not significantly correlated with changes in student performance in any of the four knowledge categories assessed.

Discussion

The purpose of this study was to explore the effectiveness of WBLTs in a secondary school environment. Five measures of impact were collected: teacher attitude survey, teacher comments, student attitude survey, student comments, and student performance. The measures were used to address three main research questions:

(1) What are teacher perceptions regarding the use of WBLTs?
(2) What are students perceptions regarding the use of WBLTs?
(3) How do WBLTs effect student performance?

What are teacher perceptions regarding the use of WBLTs?

The survey data strongly indicated that secondary school teachers thought the WBLTs they used were good quality, engaging tools that supported learning, with average ratings over six on a 7-point Likert scale. Furthermore, open-ended comments from teachers suggested teachers thought that using WBLTs increased both learning and enjoyment for students. These results are consistent with those reported previously (Kay & Knaack, 2007, 2008a, 2008c, 2009a, 2009b; McCormick & Li, 2006; Schibeci et al., 2008).

Almost 50% of the teachers had no technology problems whatsoever. Most of the remaining teachers reported experienced minor technological problems based on the quality of hardware available in the schools. These findings, coupled with the fact that most teachers thought WBLTs were easy to learn, provide evidence that WBLTs address two previously noted barriers to using technology in the classroom: having limited based computer skills and excessive time required to learn new software.

The need for carefully designed instructional wrap for WBLTs has been noted in several recent studies (Brush & Saye, 2001; Kay et al., 2009; Lowe et al., 2010, Schibeci et al., 2008). In the current study, teachers rated WBLT lesson plans and support material high with respect to ease of use, design, and matching personal teaching styles. It appears, pre-made lesson materials have the potential to address a third barrier to using computers in the classroom – not knowing how to integrate technology into a lesson.

In summary, the results of this study, along with those from previous research, provide strong evidence that secondary school teachers believe that good quality WBLTs engage students and help them learn. An important caveat, though, is supported by comments from several teachers in this study and previous research results (Brush & Saye, 2001; Kay et al., 2009; Lowe et al., 2010; Schibeci et al., 2008). A WBLT needs to be supplemented by meaningful and thoughtful guidance from the teacher. WBLTs may not be particularly successful if treated as isolated, independent teaching tools for secondary school students.

What are students perceptions regarding the use of WBLTs?

On average, secondary school students agree that the WBLTs they used were good quality, engaging learning tools that helped them learn, however, the ratings of these qualities were lower than those of their teachers. This pattern of results has been observed repeatedly in the literature (Kay & Knaack, 2007, 2008a, 2008b, 2009a). What is most noteworthy is the broad range of scores. Many students liked using WBLTs, however, a smaller group disliked using them intensely. Even though the WBLTs were carefully chosen for this study to maximize learning and engagement, it may not be possible to satisfy the learning desires of all students.

Student comments offered more insight about variability in student reactions to the learning, design, and engagement value of WBLTs. With respect to learning, many students liked the learning features of WBLTs, particularly the visual scaffolding. This finding has been consistently reported in previous research (Kay & Knaack, 2007, 2008a, 2008b, 2009a; Lowe et al., 2010; Schibeci et al., 2008). It is probably safe to conclude that when selecting WBLTs, it is beneficial to select those with meaningful visual supports, at least in the area of mathematics and science. The two features that were identified as being detrimental to learning involved challenge and pace. Specifically, students noted that some WBLTs were too difficult to understand and

that the pace of learning was too quick – they felt rushed by time constraints. This finding is unique. Several previous studies reported the opposite finding – that WBLTs were not challenging enough (Kay & Knaack, 2007, 2008a, 2008b). Finding the optimum level of cognitive challenge for all students may be difficult, regardless of teaching method used. It is probably more difficult to adjust a lesson when the WBLTs selected are too easy, however, teachers may need to provide additional guidance and direction when the WBLTs chosen prove to be too challenging.

With respect to quality of WBLTs, students commented that they were easy to use and that they liked the visual features and interactivity. What student did not like was having to read long passages of text and the quality of help features. Again, these results are consistent with those of previous studies (Kay & Knaack, 2007, 2008a, 2008b, 2009a; Lowe et al., 2010; Schibeci et al., 2008). When selecting an appealing WBLT, easy of use, quality of graphics, limited text, and effective help are good discriminating features.

Finally, regarding engagement, the WBLTs and use of technology were well received by students in this study. Many commented that the WBLTs were interesting or fun, they liked using technology, and they felt WBLTs were more effective than other teaching methods. Student enthusiasm for WBLTs is consistent with the idea that current secondary students have grown up with technology and therefore thrive when it is used in the classroom (Montgomery, 2009; Palfrey & Gasser, 2008; Tapscott, 2008).

In summary, previous research and data from the current study strongly suggest that most, but not all, secondary students react to WBLTs in a positive manner and view them as productive learning tools.

How do WBLTs effect student performance?

It is clear that learning performance increased significantly when WBLTs were used, with test scores improving from 28 to 53%. According to Thalheimer and Cook (2002), this increase is not only statistically significant, but meaningful with respect to effect size which was considered large. This increase is consistent with previous research (Kay & Knaack, 2008a, 2008b, 2009a), although the magnitude of change is higher in the current study. The sizeable impact on learning performance may be a reflection of the time spent selecting good quality WBLTs and developing effective lesson plans.

Unlike previous research, the current study examined specific type s of knowledge gained by students, based on the revised Bloom's Taxonomy (Anderson & Krathwhol, 2001). The type of questions asked of students after they used a WBLT focussed on remembering facts (86% of all questions), understanding concepts (43%), applying knowledge (42%), and analysis (24%). Significant gains were observed in all four categories, with the biggest change seen in understanding-based questions (53%) and the smallest change observed in application questions (28%). The evidence suggests, then, that WBLTs can have a positive impact on improving a wide range of knowledge areas.

Previous studies used mixed methods when integrating WBLTs or did not clearly describe the lesson plans used. The design of the current study permits one to reasonably assume that increases in student performance were largely due to the use of WBLTs. The pre-designed lesson plans were crafted to focus on using WBLTs to the exclusion of other teaching methods. A prescribed format of briefly introducing

and demonstrating the WBLT, giving students a set of guiding questions, and consolidating the lesson at the end was employed in most lesson plans.

Finally, students in this study performed better after using WBLTs regardless of their average grade, comfort level in the subject area where the WBLT was used, and ability to use computers. This finding suggests that increases in performance due to the use of WBLTs are fairly robust.

Implications for education

The results of this study lead to several implications for secondary school teachers who plan to use WBLTs in their classrooms. First, both teachers and students find WBLTs easy to use, therefore computer skill level will not be a significant barrier. Second, both teachers and students are positive about the learning impact and added engagement value the WBLTs bring to the classroom. Third, since visual supports are highly rated, it is a good idea to select WBLTs based on this feature. Fourth, WBLTs have the potential to improve student understanding of both basic and higher level concepts. Fifth, carefully planned lessons appear to enhance the learning impact of WBLTs – these tools are typically not designed for independent learning. Finally, teachers need to be conscious of potential problems associated with going to fast, difficulty level, and amount of text. While WBLTs are easy to use, the concepts presented may be challenging particularly when the pace of learning is too quick or there is excessive text to read.

Caveats and future research

In this study, a series of steps was followed to improve the quality data collection and analysis including controlling for the quality of WBLTs and lesson plans, collecting data from a relatively large sample size, using a wide range of WBLTs, employing reliable, valid assessment tools, and gathering both quantitative and qualitative information. Nevertheless, several limitations exist which provide opportunities for future research endeavors.

First, even though the student population was relatively large and balanced in terms of gender, the conclusions offered of this study are restricted to the domains of science and to a lesser extent mathematics. Different results in terms of engagement and the type of knowledge gained by using WBLTs might be influenced by the subject area taught.

Second, while an attempt was made to explore different types of knowledge gains based on the revised Blooms taxonomy, more research is needed to confirm whether WBLTs can consistently improve a wide range of knowledge areas.

Finally, while a mixed methods approach was used to assess the impact of WBLTs, the use of interviews and focus groups could enhance the interpretation of data. For example, it would be helpful to understand why there is so much variability with respect to student reactions to WBLTs, even within the same class. Is this variability inevitable or are there strategies that can help address those students who are disinterested or confused?

Notes on contributor

Robin Kay has published over 50 articles or chapters in the area of computers in education, presented numerous papers at 15 international conferences, is a reviewer for five prominent

computer education journals, and has taught computers, mathematics, and technology for over 18 years at the high school, college and university level. Current projects include research on laptop use in teacher education, learning objects, classroom response systems, gender differences in computer related behaviour, discussion board use, emotions and the use of computers, and factors that influence how students learn with technology. He completed his Ph.D. in Cognitive Science (Educational Psychology) at the University of Toronto, where he also earned his masters degree in Computer Applications in Education. He is currently an Associate Professor in the Faculty of Education at the University of Ontario Institute of Technology in Oshawa, Canada.

References

Agostinho, S., Bennett, S., Lockyer, L., & Harper, B. (2004). Developing a learning object metadata application profile based on LOM suitable for the Australian higher education market. *Australasian Journal of Educational Technology*, *20*, 191–208. Retrieved from http://www.ascilite.org.au/ajet/ajet20/agostinho.html

Anderson, L.W., and Krathwohl, D.R. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. New York: Longman.

Barkley, E.F. (2010). *Student engagement techniques*. San Francisco: John Wiley & Sons.

Bartlett, A. (2002). Preparing preservice teachers to implement performance assessment and technology through electronic portfolios. *Action in Teacher Education*, *24*(1), 90–97.

Bransford, J.D., Brown, A.L., & Cocking, R.R. (Eds.). (2000). *How people learn*. Washington, DC: National Academy Press.

Bruner, J. (1986). *Actual minds, possible worlds*. Cambridge, MA: Harvard University Press.

Brush, T., Glazewski, K., Rutowski, K., Berg, K., Stromfors, C., Van-Nest, M., . . . Sutton, J. (2003). Integrating technology in a field-based teacher training program: The PT3@ASU project. *Educational Technology, Research and Development*, *51*(1), 57–73. doi: 10.1007/BF02504518

Brush, T., & Saye, J. (2001). The use of embedded scaffolds with hypermedia-supported student-centered learning. *Journal of Educational Multimedia and Hypermedia*, *10*, 333–356.

Bullock, D. (2004). Moving from theory to practice: An examination of the factors that preservice teachers encounter as the attempt to gain experience teaching with technology during field placement experiences. *Journal of Technology and Teacher Education*, *12*, 211–237.

Butson, R. (2003). Learning objects: Weapons of mass instruction. *British Journal of Educational Technology*, *34*, 667–669. doi: 10.1046/j.0007-1013.2003.00359.x

Collins, A.C., & Haverson, R. (2009). *Rethinking education in the age of digital technology*. New York: Teachers College Press.

Compton, V., & Harwood, C. (2003). Enhancing technological practice: An assessment framework for technology education in New Zealand. *International Journal of Technology and Design Education*, *13*(1), 1–26. doi: 10.1023/A:1022318118467

Cuban, L. (2001). *Oversold and underused: Computers in the classroom*. Cambridge, MA: Harvard University Press.

Doering, A., Hughes, J., & Huffman, D. (2003). Preservice teachers: Are we thinking with technology? *Journal of Research on Technology in Education*, *35*, 342–361.

Eifler, K. Greene, T., & Carroll, J. (2001). Walking the talk is tough: From a single technology course to infusion. *The Educational Forum*, *65*, 366–375.

Gay, L.R., Mills, G.E., Airasian, P. (2009). *Educational research* (9th ed.). Upper Saddle River, NJ: Pearson Education.

Kafai, Y.B. (2006). Constructionism. In R.K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 35–46). New York: Cambridge University Press.

Kay, R.H. (2010a). Appendix A – List of WBLTs used in secondary school study. Retrieved November 2, 2011, from http://faculty.uoit.ca/kay/res/lo/ss.html

Kay, R.H. (2010b). Appendix B – WBLT survey for teachers. Retrieved November 2, 2011, from http://faculty. uoit.ca/kay/res/lo/ts.pdf

Kay, R.H. (2010c). Appendix C – WBLT survey for students. Retrieved November 2, 2011, from http://faculty.uoit.ca/kay/res/lo/ss.pdf

Kay, R.H. (2010d). Appendix D – Coding scheme to assess student comments about WBLTs. Retrieved November 2, 2011, from http://faculty.uoit.ca/kay/res/lo/cs.pdf

Kay, R.H. (2010e). Appendix E – Sample comments from students using WBLTs. Retrieved from http://faculty.uoit.ca/kay/res/lo/sc.pdf

Kay, R., & Knaack, L. (2005). Developing learning objects for secondary school students: A multi-component model. *Interdisciplinary Journal of Knowledge and Learning Objects*, *2005*(1), 229–254. Retrieved from http://www.ijello.org/Volume1/v1p229-254Kay_Knaack.pdf

Kay, R.H., & Knaack, L. (2007). A systematic evaluation of learning objects for secondary school students. *Journal of Educational Technology Systems*, *35*, 411–448. doi: 10.2190/M770-J104-V701-8N45

Kay, R.H., & Knaack, L. (2008a). An examination of the impact of learning objects in secondary school. *Journal of Computer Assisted Learning*, *24*, 447–461. doi: 10.1111/j.13 65-2729.2008.00278.x

Kay, R.H., & Knaack, L. (2008b). A multi-component model for assessing learning objects: The learning object evaluation metric (LOEM). *Australasian Journal of Educational Technology*, *24*, 574–591. Retrieved from http://www.ascilite.org.au/ajet/ajet24/kay.pdf

Kay, R.H., Knaack, L., & Muirhead, B. (2009). A formative analysis of instructional strategies for using learning objects. *Journal of Interactive Learning Research*, *20*, 295–315.

Kay, R.H., & Knaack, L. (2008c). Investigating the use of learning objects in secondary school mathematics. *Interdisciplinary Journal of E-Learning and Learning Objects*, *4*, 269–289. Retrieved from http://ijello.org/Volume4/IJELLOv4p269-289Kay.pdf

Kay, R.H., & Knaack, L. (2009a). Analyzing the effectiveness of learning objects for secondary school science classrooms. *Journal of Educational Multimedia and Hypermedia*, *18*(1), 113–135.

Kay, R.H., & Knaack, L. (2009b). Assessing learning, quality and engagement in learning objects: The learning object evaluation scale for students (LOES-S). *Education Technology Research and Development*, *57*, 147–168. doi: 10.1007/s11423-008-9094-5

Kay, R.H., Knaack, L., & Petrarca, D. (2009). Exploring teacher perceptions of web-based learning tools. *Interdisciplinary Journal of E-Learning and Learning Objects*, *5*, 27–50. Retrieved from http://ijklo.org/Volume5/IJELLOv5p027-050Kay649.pdf

Koehler, M.J., & Mishra, P. (2008). Introducing TPCK. In AACTE Committee on Innovation and Technology (Ed.), *Handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. 1–29). New York: Routledge.

Lopez-Morteo, G., & Lopez, G. (2007). Computer support for learning mathematics: A learning environment based on recreational learning objects. *Computers and Education*, *48*, 618–641. doi: 10.1016/j.compedu.2005.04.014

Lowe, K., Lee, L., Schibeci, R., Cummings, R., Phillips, R., & Lake, D. (2010). Learning objects and engagement of students in Australian and New Zealand schools. *British Journal of Educational Technology*, *41*, 227–241. doi: 10.1111/j.1467-8535.2009.00964.x

McCormick, R., & Li, N. (2006). An evaluation of European learning objects in use. *Learning, Media and Technology*, *31*, 213–231. doi: 10.1080/17439880600893275

McGreal, R. (2004). learning objects: A practical definition. *International Journal of Instructional Technology and Distance Learning*, *1*. Retrieved from http://www.itdl.org/Journal/Sep_04/article02.htm

McMillan, J.H., & Schumacher, S. (2010). *Research in education* (7th ed.). Upper Saddle River, NJ: Pearson Education.

McRobbie, C.J., Ginns, I.S., & Stein, S.J. (2000). Preservice primary teachers' thinking about technology and technology education. *International Journal of Technology and Design Education*, *10*(1), 81–101. doi: 10.1023/A:1008941520152

Medina, J. (2008). *Brain rules*. Seattle, WA: Pear Press.

Miles, M.B., & Huberman, A.M. (1994). *Qualitative data analysis* (2nd ed.). Thousand Oaks, CA: Sage Publications.

Montgomery, K.C. (2009). *Generation digital*. Cambridge, MA: MIT Press.

Palfrey, J., & Gasser, U. (2008). *Born digital*. New York: Basic Books.

Parrish, P.E. (2004). The trouble with learning objects. *Educational Technology Research & Development*, *52*(1), 49–67. doi: 10.1007/BF02504772

Patton, M.Q. (2002). *Qualitative research & evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage Publications.

Plante, J., & Beattie, D. (2004). *Education, skills, and learning – Research papers Connectivity and ICT integration in Canadian elementary and secondary schools: First results from the Information and Communications Technologies in Schools Survey, 2003–2004*. Statistics Canada. Retrieved from http://www.schoolnet.ca/home/documents/Report_EN.pdf

Robertson, H. (2003). Toward a theory of negativity: Teacher education and information and communications technology. *Journal of Teacher Education*, *54*, 280–296. doi:10.1177/0022487103255499

Russell, M., Bebell, D., O'Dwyer, L., & O'Connor, K. (2003). Examining teacher technology use: Implications for preservice and inservice teacher preparation. *Journal of Teacher Education*, *54*, 297–310. doi: 10.1177/0022487103255985

Schibeci, R., Lake, D., Phillips, R., Lowe, K., Cummings, R., & Miller, E. (2008). Evaluating the use of learning objects students in Australian and New Zealand schools. *Computers & Education*, *50*(1), 271–283. doi:10.1016/j.compedu.2006.05.006

Sedig, K., & Liang, H. (2006). Interactivity of visual mathematical representations: Factors affecting learning and cognitive processes. *Journal of Interactive Learning Research*, *17*, 179–212.

Sousa, D.A. (2006). *How the brain learns* (3rd ed.). Thousand Oaks, CA: Corwin Press.

Strudler, N., Archambault, L., Bendixen, L., Anderson, D., & Weiss, R. (2003). Project THREAD: Technology helping restructure educational access and delivery. *Educational Technology Research and Development*, *51*(1), 39–54.

Tapscott, D. (2008). *Grown up digital: How the net generation is changing your world*. New York: McGraw-Hill.

Thalheimer, W., & Cook, S. (2002). How to calculate effect sizes from published research articles: A simplified methodology. Retrieved from http://work-learning.com/effect_sizes.htm

Thompson, A.D., Schmidt, D.A., & Davis, N.E. (2003). Technology collaboratives for simultaneous renewal in teacher education. *Educational Technology Research and Development*, *51*(1), 73–89. doi: 10.1007/BF02504519

Vygotsky, L.S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.

Wepner, S.B., Ziomek, N., & Tao L. (2003). Three teacher educators' perspectives about the shifting responsibilities of infusing technology into the curriculum. *Action in Teacher Education*, *24*, 53–63.

Wiley, D., Waters, S., Dawson, D., Lambert, B., Barclay, M., & Wade, D. (2004). Overcoming the limitations of learning objects. *Journal of Educational Multimedia and Hypermedia*, *13*, 507–521.

Williamson, J., & Redish, T. (2009). *ISTE's technology facilitation and leadership standards – What every K-12 leader should know and be able to do*. Washington, DC: ISTE.

Willingham, D.T. (2009). *Why don't students like school?* San Francisco: Jossey-Bass.

Wlodkowski, R.J. (2008). *Enhancing adult motivation to learn: A comprehensive guide for teaching all adults*. San Francisco: Jossey-Bass.