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Exploring the Impact of Web-Based Learning Tools in Middle School Mathematics and Science Classrooms

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This study examined the impact of Web-Based Learning Tools (WBLTs), also known as learning objects, in middle school mathematics and science classrooms. Survey, qualitative, and student performance data were collected from a sample of 18 teachers and 443 students. Teachers were very positive about the learning benefits, design of WBLTs, and increased engagement of their students. Students were moderately positive about these same features. Student learning performance with respect to remembering, understanding, applying and evaluating concepts increased significantly when WBLTs were used. Qualitative data suggested that a number of students enjoyed the visual supports, ease of use, and interactivity of WBLTs as well using technology to learn. Some students noted that the WBLTs used in class were not challenging enough and that the help features and the design of certain WBLTs were deficient. Overall, it is reasonable to conclude that WBLTs, if selected carefully, can be a positive and effective learning tool in a middle school environment.

Overview

Research and use of Web-Based Learning Tools (WBLTs), also referred to as learning objects, has been conducted primarily in higher education (e.g., Haughey & Muirhead, 2005; Kay & Knaack, 2008, 2009). Recently, there has been an increase in the implementation of WBLTs in middle

schools (e.g., Bower, 2005; Kay & Knaack, 2008c; Liu & Bera, 2005; Nurmi & Jaakkola, 2006; Reimer & Moyer, 2005). However, research on the effectiveness and usefulness of WBLTs in the middle school domain is limited, partially because comprehensive, theoretically-based, reliable, and valid evaluation tools are scarce. The purpose of the current study was to systematically and comprehensively assess the impact of WBLTs in middle school classrooms by exploring student and teacher attitudes, as well as learning performance.

LITERATURE REVIEW

Definition and Benefits of WBLTs

WBLTs are operationally defined in this paper as "interactive web-based tools that support learning of a concept by enhancing, amplifying, and guiding the cognitive processes of learners". WBLTs permit to students to experiment, manipulate variables, apply concepts, or answer questions based on formal presentation of material targeting a relatively narrow concept. This definition was derived from an amalgamation of previous attributes of learning objects (Agostinho, Bennett, Lockyer & Harper, 2004; Butson, 2003; McGreal , 2004; Parrish, 2004; Wiley, et al. 2004). Learning objects have been defined quite broadly in the past and have been known to include web pages, lectures, complete courses as well as interactive tools. The term "web-based learning tool" is used in this study instead of "learning object" because it more accurately reflects the qualities of interactivity, focussing on a specific concepts, and scaffolding.

Many teachers experience a number challenges when trying to use computers in their classrooms including the amount of time required to learn new software (Eifler, Greene, & Carroll, 2001; Wepner, Ziomek, & Tao, 2003), fear and anxiety associated with using technology (Bullock, 2004; Doering, Hughes, & Huffman., 2003), limited technological skills (Eifler et al., 2001; Strudler, Archambault, Bendixen, Anderson & Weiss, 2003; Thompson, Schmidt, & Davis, 2003), and insufficient access to software and hardware (Bartlett, 2002; Brush et al., 2003; Russell , Bebell, O'Dwyer, & O'Connor, 2003). WBLTs present several advantages that directly address these challenges.

Most WBLTs are designed to focus on a single concept and are very easy to use (e.g., Gadanidis, Gadanidis, & Schindler, 2003; Kay & Knaack, 2008b, 2008c, 2009; Sedig & Liang, 2006). The time and skills required

by teachers and students to learn how to use WBLTs are minimal, thereby decreasing preparation time and increasing instructional time. Ease of use also has the potential to alleviate fears associated with using computers (e.g., Kay & Knaack, 2008b, 2008c, 2009). Additionally, WBLTs are often free of charge and readily accessible on the Internet. Since high speed access to the web is available in a majority of schools in a number of countries (e.g., Compton & Harwood, 2003; OECD, 2006) teachers have relatively quick access to a wide range of WBLTs. They need not worry about having software installed or needing the latest version of a tool (Kay & Knaack, 2008b, 2008c, 2009).

With respect to learning, many WBLTs have visual components that help make abstract concepts more accessible (Gadanidis et al., 2003; Kay & Knaack, 2008b, 2008c). Furthermore, some WBLTs allow students to explore higher level concepts by reducing cognitive load (Sedig & Liang, 2006). Finally, WBLTs allow users to have a certain degree of control over their learning environment, particularly the pace of learning (Kay, 2008b, 2008c).

In summary, WBLTs have the potential to help overcome challenges that many teachers experience when using computers in the classroom, as well as improve the quality of student learning.

WBLTs in Middle Schools

A review of the literature over the past 10 years uncovered six peer-reviewed studies targeting the use of WBLTs in middle school (Akpinar & Bal, 2006; Bower, 2005; Kay & Knaack, 2008c; Kong & Kwok, 2005; Liu & Bera, 2005, Nurmi & Jaakkola, 2006). These papers, dating back no further than 2005, indicate that research in this domain is fairly new.

Teacher perspective. Only one report examined teacher attitudes toward the use of WBLTs in the classroom (Kay & Knaack, 2008c). Survey data collected suggested that instructors were positive about the learning benefits, design, and engagement value of WBLTs - more positive than students. Qualitative data suggested that teachers believed that the main benefits of using WBLTs were improving the quality of learning and getting students more engaged in the lesson.

Student perspective. Only one study assessed middle school student attitudes toward WBLTs (Kay & Knaack, 2008c). Students were moderately positive about the design and learning benefits of WBLTs and claimed they were more engaged when using these tools. Students preferred WBLTs

that were easy to use and had good interactivity, visual supports, animations, and graphics. They did not like WBLTs that were too easy, nor did they like the limited quality of help features and excessive amounts of text.

Student performance. The majority of studies conducted on the use of WBLTs in middle schools focussed on some form of student performance (Akpinar & Bal, 2006; Bower, 2005; Kong & Kwok, 2005, Kay, 2008c; Liu & Bera, 2005). In all five studies, the use of WBLTs resulted in significant gains in performance.

Overall, research on the use of WBLTs in middle schools is minimal, although preliminary evidence suggests that these tools are positively received by both teachers and students and result in significant gains in learning performance.

Methodological Issues

This study reviewed six articles looking at the use of WBLTs in middle school classrooms. While solid data has been presented with respect to student performance, several methodological concerns need to be addressed.

First, limited information is offered regarding teachers' attitudes toward WBLTs. Only one study examined WBLTs from the teacher's perspective (Kay, 2008c). Second, the majority of studies examined the use of a single WBLT, thereby limiting the scope of the results reported. Third, sample populations tested in most papers were relatively small and inadequately described making it challenging to generalize any conclusions to a larger population. Fourth, triangulation of data collection was absent in all but one study (Kay & Knaack, 2008c). Finally, while most evaluation studies reported that students benefited from using WBLTs, the evidence is based on loosely designed assessment tools with no validity or reliability. Only three studies reviewed offered estimates of reliability (Kong & Kwok, 2005; Kay & Knaack, 2008c; Liu & Bera, 2005) and only one study provided validity data (Kay & Knaack, 2008c).

It is worth noting that Kay & Knaack (2008c) addressed most of the methodological concerns listed above. However, they did not address several important issues in their study including controlling the quality of WBLTs and lesson plans used, standardization of student learning performance measures, and assessing a broader range of cognitive skills when WBLTs were used. The current study addresses each of these concerns.

Purpose

The purpose of this study was to examine the impact of WBLTs in middle 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 used where possible ;
3. formal statistics were used when appropriate;
4. a wide range of high quality math and science-based WBLTs were pre-selected based on the Kay & Knaack's (2008a) 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. This sample consisted of 443 middle school students (198 males, 245 females), 12 to 15 years of age (M = 145, SD = 0.54). Over 80% (n=355) of the students reported an average mark 70% or more in the subject area where the WBLT was used - either mathematics or science. In addition, over three quarters of students agreed or strongly agreed that that they were good at working with computers. The sample population was gleaned from two boards of education and 18 different classrooms located in a region with a population of 300,000 people.

Teachers. This sample consisted of 18 teachers (6 males, 12 females). Fifty percent of the teachers taught grade 7 and 50% taught grade 8. Subject areas targeted were science (n=6 classes) and math (n=12 classes). Teaching experience ranged from 0.5 to 23 years with a mean of 9.6 (SD = 7.0). Approximately 70% (n=13) of the teachers agreed that they were good at and liked working with computers at school. In terms of frequency of use, about 60% (n=11) of teachers used the computers on a monthly basis or less.

WBLTs and lesson plans. Four mathematics and science teachers not involved in the study were trained for two days on how to select WBLTs for the classroom and develop effective lesson plans. The WBLTs were selected based on the criteria outlined in Kay & Knaack's (2008a) multi-component model for assessing WBLTs and included four main features: interactivity, design, engagement, and usability. The lesson plan design was based on the results from a previous research study by Kay, Knaack, & Muirhead (2009). Key features of each lesson plan included a guiding set of questions, a structured well-organized format for using the WBLTs, and time to consolidate concepts learned. All lessons were designed to be approximately 70 minutes in length with a 10 minute introduction, 50 minutes of WBLT use, and a 10 minute consolidation.

Over a period of 2 months, a database of 122 WBLTs was created with corresponding lesson plans, and pre/post tests (78 for mathematics and 44 for science). A total of 10 unique WBLTs were chosen from the WBLT database and used by classroom teachers in this study. A wide variety of WBLTs were used involving experimentation, virtual manipulatives, task-based applications, and formal presentation of concepts followed by a question and answer assessment. See Appendix A (Kay, 2009a) for a complete list of links to all WBLTs used 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, survey and test data was only collected from those students with signed parental permission forms. These tests were pre-designed by the authors of the lesson plans to match the teaching goals of the WBLT.

Data Sources

Teacher survey. Each teacher completed the WBLT Evaluation Scale for Teachers to assess their perceptions of how much students learned (learning construct - 4 items), the design of the WBLT (design construct

- 3 items) and the degree to which students were engaged when using the WBLT (engagement construct - 4 items). The constructs selected were based on a thorough review of the literature (Kay & Knaack, 2005, 2007). The scale showed fair to moderate reliability and good construct validity (see Kay, Knaack, & Petrarca, 2009). Internal scale reliability estimates for the current study were 0.94 (perceived learning), 0.85 (design of WBLT), and 0.85 (engagement). See Appendix B (Kay, 2009b) for a copy of the teacher survey used in this study.

Teacher comments. Teachers were asked three open ended questions about (a) the overall impact that the WBLT had on learning, (b) technical issues they experienced, and (c) advice they had for future teachers who might want to use WBLTs.

Student survey. After using a WBLT, students completed the WBLT Evaluation Scale for Students to assess their perceptions of how much they had learned (learning construct- 6 items), the design of the WBLT (design construct - 4 items) and how much they were engaged when using the WBLT (engagement construct - 4 items). The constructs selected were based on a thorough review of the literature (Kay & Knaack, 2005, 2007, 2009). The scale showed good reliability, face validity, construct validity, convergent validity and predictive validity (Kay & Knaack, 2009). Internal-reliability scale estimates in the current study were 0.94 (perceived learning), 0.87 (design of WBLT), and 0.93 (engagement). See Appendix C (Kay, 2009c) for a copy of the scale used.

Student comments. Students were asked open-ended questions about what they liked and disliked about the WBLT they used. The responses were organized according to the coding scheme provided in Appendix D (Kay, 2009b). This coding scheme was used to categorize 722 student comments. Each comment was then rated on a five-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 re-rated the comments. A final inter-rated reliability of 98% was achieved for both categories and numerical ratings.

Note that the total impact of any one category was determined by multiplying the mean category rating by the total number of students who made a comment. For example, from table 3, the impact of visual supports on learning was calculated by multiplying the mean (M = 1.02) by the number of students who commented about visual supports (n =49) for a total of 50.0.

Student performance. Students completed a pre- and post-test based on the content of the WBLT used in class. All tests consisted of two to six questions worth a total of five to eight marks. The type of questions varied according to the learning goals of the WBLT and included open-ended responses, short-answer, multiple choice, fill in the blank, and application problems. These tests were created by the lesson plan designers to match the teaching goals of the WBLT. The difference between pre- and post-test scores was used to determine student performance on five possible categories of questions: remembering, understanding, application, analysis, and evaluation. These categories were derived from the revised Bloom's Taxonomy (Anderson & Krathwhol, 2001). The number of question categories assessed varied according to the type of the WBLT used and the learning goals targeted in the lesson.

Key Questions & Data Analysis

In order to examine the impact of WBLTs on middle school students, the following questions were addressed in the data analysis:

1. How do teachers rate learning, design and engagement of WBLTs? (teacher survey)
2. What are teachers' perceptions of overall impact, technological challenges experienced, and suggestions for future teachers? (open-ended questions from teachers)
3. How do students rate learning, design 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

Since the lesson plans for the WBLTs were designed by other teachers, it is important to evaluate the extent to which teachers in this study accepted and adapted to these lesson plans. Ninety-four percent of the teachers

agreed or strongly agreed that the lesson plans were easy to follow. Over 80% (n=15 out of 18) of teachers believed that the lesson plan matched their teaching style. Almost 75% of the teachers felt the handouts were clear and 90% believed they were useful. Almost 90% of teachers felt the lesson plans were well designed and 83% felt there was no need to make changes.

Teacher Rating of WBLTs

Learning. The mean rating for impact on learning (Items 8a to 8d – Appendix B in Kay, 2009b) was 23.8 (*SD* = 3.06) or an average of 5.9 on a 7-point Likert scale (1 = Strongly Disagree, 7= Strongly Agree). This indicates that most teachers agreed that the WBLT had a positive impact on student learning (Table 1).

Design of WBLT. The mean rating of WBLT design (Items 7a to 7c – Appendix B in Kay, 2009b) was 18.0 (*SD* = 2.8) or and average of 6.0 on a 7-point scale. Most teachers agreed or strongly agreed the WBLT was well designed (Table 1).

Engagement. Teachers also rated engagement of WBLTs (Items 9a to 9d – Appendix B in Kay, 2009b) high with a mean score of 24.7 (SD = 2.8) or and average of 6.2 on a 7-point scale (Table 1). This means that most teachers agreed that the WBLTs were engaging for students.

Table 1

Teacher Rating of Learning, Design, and Engagement for WBLTs

Scale	No. Items	Possible Range	Actual Range Observed	Mean (S.D)
Learn	4*	4 to 28	15 to 28	23.8 (3.1)
Design	3*	3 to 21	12 to 21	18.0 (2.8)
Engagement	4*	4 to 28	16 to 28	24.7 (2.8)

* each item is based on a 7 point Likert Scale (1=Strongly Disagree, 2 = Strongly Agree, 3= Slightly Agree, 4 = Neutral, 5 = Slightly Agree, 6 = Agree, 7 = Strongly Agree)

Teacher comments – overall impact. According to seven teachers in this study, the main impact of the WBLTs was on improving learning. Sample comments were:

"I saw an improvement in student performance"
"I was happy with the students' understanding and progress"
"The WBLT really affirmed for the students the concept at hand"

Other comments referred to student engagement. Samples comments were:
"It definitely was a nice change to be out of the classroom"
"The students who really enjoy computers, loved doing the lesson using the WBLT"
"The students were actively engaged and enjoyed the activity"

Overall, these comments are consistent with the positive ratings recorded from the teacher survey data.

Teacher comments – technology problems. Eight of the 18 teachers reported no problems at all using the WBLT technology. Issues that did arise included students having trouble typing in a long web address pointing to the WBLT, computers freezing or not working, slow computers, and videos not being able to be displayed on student computers. Overall, no major 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 "just do it" – four teachers were very positive about using WBLTs and strongly encourage other teachers to use them The second theme was time – five teachers noted that it takes more time to use WBLTs than they expected. The final theme, noted by two teachers, was to demonstrate the WBLT to the class before the students use it.

Student Rating of WBLTs

Learning. Students rated WBLTs lower than teachers with respect to learning (Items 8a to 8f – Appendix C in Kay, 2009c) (M=29.5, SD = 8.4) with a mean item rating of 4.9 out of 7. This means that students, on average, "slightly agreed" that WBLTs helped them learn. The broad range of scores (6 to 42) indicates that there was considerable variability within this construct (Table 2).

Design of WBLTs. Students rated the design of WBLTs (Items 7a to 7d – Appendix C in Kay, 2009c) slightly higher than the learning value (M=21.1, SD = 5.1), although the mean item rating (5.3 out of 7) was still lower than that of the teachers. The range of WBLT design scores (4 to 28) showed considerable variability in responses (Table 2).

Engagement. Student ratings of WBLT engagement (Items 9a to 9d – Appendix C in Kay, 2009c) were moderate (*M*=19.1, *SD* = 6.4) with a mean item rating of 4.8 out of 7. This means that students, on average, "slightly agreed" that the WBLT they used was engaging. High variability among student engagement ratings is supported by the wide range of scores reported (4 to 38).

Table 2

Student Rating of Learning, Design, and Engagement for WBLTs

Scale	No. Items	Possible Range	Actual Range Observed	Mean (S.D)
Learn	6*	6 to 42	6 to 42	29.5 (8.4)
Design	4*	4 to 28	4 to 28	21.0 (5.1)
Engagement	4*	4 to 28	4 to 28	19.1 (6.4)

* each item is based on a 7 point Likert Scale (1=Strongly Disagree, 2 = Strongly Agree, 3= Slightly Agree, 4 = Neutral, 5 = Slightly Agree, 6 = Agree, 7 = Strongly Agree)

Student comments about WBLTs

A number of specific categories emerged from over 700 student comments summarized in table 3. Categories where more than 10 comments were made will be discussed in detail.

Table 3

Summary of Student Comments about WBLTs

Category	Mean	SD	Total	Total Neg.	Total Pos.	Total Effect Mean * n
General						
General/Overview	0.06	1.62	84	31	49	5.0
Learning						
Visual Supports	1.02	0.72	49	3	46	50.0
Overall Learning	0.32	1.24	91	25	65	29.0
Pace	0.20	1.03	10	5	6	2.0
Challenge	-1.01	0.86	67	60	7	-68.0

Table 3 continued

Design						
Easy to Use	0.64	1.06	50	10	39	32.0
Interactive	0.66	0.90	29	6	23	19.0
Graphics	0.05	1.20	37	18	19	2.0
Theme	0.03	1.25	35	16	19	1.0
Control	-0.25	1.50	4	2	2	-1.0
Audio	-1.00		1	1	-	-1.0
Text	-1.33	0.58	3	3	-	-4.0
Help	-0.86	1.06	29	25	4	-25.0
Organization	-1.11	1.06	33	27	6	-28.0
Engagement						
Technology	0.71	0.86	65	9	56	46.0
Compare	0.88	0.79	40	4	36	35.0
Engaging	0.01	1.16	80	39	41	1.0

General attitudes. With respect to "general" comments about WBLTs, students appeared to be divided. Roughly 50% of the students made positive comments and 50% made negative comments. Typical comments were :

"I liked mostly everything."
"I like using the WBLT so nothing was bad for me. "
"I liked nothing."
"It [was] pointless."

Learning. With respect to learning, the visual supports category was rated the highest for some WBLTs with 46 positive and three negative comments. Representative statements included:

"[The WBLT] helped you visualize what the information was saying."
"Picture diagrams where you move lines helped teach the concept well."
"The diagrams helped me understand the process of transpiration."

Ratings of overall learning were largely positive with 65 positive and 25 negative comments. Characteristic comments included:

"It made me review a learn and little bit more."
"It gave examples so I knew how they were used."

"It helped me understand the concept even better."
"The WBLT was very hard to follow and understand."
"We didn't learn enough for the time we spent on the computers."

Ratings of challenge were rated the lowest in the learning category with 60 negative and seven positive comments. Some WBLTs were viewed as either too easy are too difficult to understand. Typical comments included:

"The questions were too easy and limited."
"It gave away all the answers."
"It was complicated."
"The WBLT was very hard to follow and understand."

Design. With respect to rating the design of certain WBLTs, ease of use was the highest rated feature with 39 positive and 10 negative comments. Representative statements were:

"I liked how easy it was to use."
"It was simple to use."
"Easy to follow."
"Not easy to use, but I get the concept."

Interactivity was also rated high for some WBLTs with 23 positive and 6 negative comments. Standard comments included:

"What I liked was exploring the [math] nets."
"I liked how it was more interactive."
"I liked that you could work interactively with the ratios and numbers."

A number of students were divided on whether they enjoyed the quality of graphics of particularly WBLTs with 19 positive and 18 negative comments. Typical comments were:

"They had good graphics and neat fonts."
"I like that there were lots of pictures and diagrams."
"I did not like the graphics."
"I thought the colours were a bit bland."

Certain students were also mixed on the theme of WBLTs with 19 positive and 16 negative comments. Sample comments included:

"I liked the treasure hunt."
"I liked playing the integer game."
"I hated learning about plants. I found that part boring."
"It was childish for older grades."

Some students were decidedly negative about the organization of WBLTs with 27 negative and 4 positive comments. Representative statements were:

"I did not like the way it was organized."
"At times I found the places to click for information difficult to find."
"Some things were a little unorganized and could have been presented a little more neatly."

A number of students did not appreciate the quality of help and instructions provided by some WBLTs, with 25 negative and 4 positive comments. Typical comments were:

"The instructions weren't easy to follow."
"If help was needed then there should have been a special way like a help button."
"I couldn't get much help [from the WBLT]."

Engagement. Regarding engagement, using technology was the highest rated category with 56 positive and nine negative comments. Representative statements were:

" I liked the fact that we could use computers."
" We got to try it on the computer which many students enjoy."

Some students also preferred using WBLTs compared to other teaching methods with 35 positive and four negative comments. Typical comments included:

" It was a lot better then sitting in a classroom and doing work and listening to the teacher giving lessons."
" It was more fun then reading it out of a textbook."

Finally, students offered mixed ratings of WBLT engagement with 41 positive and 39 negative comments. Standard comments included :

"It was fun and useful."
"I liked that you could learn at the same time as playing."
"It was kind of boring."
"It was very monotonous."

Teacher vs. Student Ratings of WBLTs

As noted above, teachers were more positive than students with respect to all three qualities of WBLTs assessed: learning, design, and engagement. Teacher ratings of learning(r = 0. 70, p <.005) and design (r = 0. 73, p <.005) were significantly correlated with student ratings. However, teacher and student ratings of engagement were not significantly correlated.

Student Performance

Five paired-tests were conducted to assess differences between pre- and post-test scores on the five Bloom's categories of questions assessed. Note that while a MANOVA is perhaps a better statistical procedure to use, not all question categories were asked for each WBLT. A group comparison eliminated considerable data and it was decided that the multiple t-tests was a better procedure to follow in order to reflect the maximum amount of data collected. All question categories showed significant increases in test scores with the exception of the "analysis" category. Increases in scores ranged from ten to 25 percent resulting in moderate to large effect sizes (Cohen, 1988, 1992). WBLTs in this study appeared to focus on application and remembering knowledge areas the most and analysis and evaluation questions the least.

Table 4
Pre-Post Test Score Differences

Question Type	Pre-Test Mean (%)	Post Test Mean (%)	n	t	Effect Size
Remembering	61.6 (± 5.9)[1]	74.3 (± 5.4)	165	-3.77 **	0.34
Understanding	39.9 (± 8.5)	64.2 (± 8.7)	90	-4.71 **	0.58
Application	63.4 (± 3.8)	73.1 (± 3.6)	268	-5.11 **	0.32
Analysis	23.6 (± 9.3)	26.3 (± 9.3)	18	-0.42	
Evaluation	60.4 (± 15.6)	83.3 (± 15.5)	24	-2.70 *	0.64
Total Score	59.2 (± 3.0)	71.7 (± 2.9)	333	-7.73 **	0.45

[1] 95% confidence intervals
* $p < .05$
** $p <.001$

It is worth noting that a student's average grade and comfort level with the subject area in which the WBLT was used were not significantly cor-

related with changes in student performance. In other words students who typically did poorly in or did not like the subject in which the WBLT was used performed as well as students who did well in or liked the subject.

DISCUSSION

The purpose of this study was to examine the effectiveness of WBLTs in a middle school environment. Five measures of impact were collected including a teacher attitude survey, teacher comments about overall impact, a student attitude survey, student comments about what they liked and did not like, and student performance. The results from each of these measures will be discussed in turn.

Teacher Ratings and Comments (Learning, Design, and Engagement)

Teachers in this study felt that the WBLTs they used were well-designed, engaging tools that supported learning, with average ratings hovering around six on a seven-point Likert scale. Most teachers were also positive about the quality of lesson plans and supporting materials. Open-ended comments from teachers were consistent with the survey data – the main impact of the WBLTs was improving learning and/or increasing engagement.

While several minor technological problems were experienced, most were related to the quality of hardware available in the schools. The absence of software related problems (e.g., Kay & Knaack, 2008b, 2008c, 2009) is one of the reported advantages of using WBLTs and is confirmed by the results.

While the data in this study reflects the attitudes and beliefs of a relatively small number of middle school teachers, the results are consistent with a similar study (Kay & Knaack, 2008c) and provide additional evidence that WBLTs are well accepted in a middle school environment.

Student Ratings and Comments (Learning, Design, and Engagement)

Overall, students in this study were less enthusiastic than teachers about the learning impact, design, and engagement value of WBLTs. On average, they "slightly agreed" that the WBLTs they used were well-designed,

engaging learning tools. These results are consistent with those reported by Kay & Knaack (2008c). The range of student scores was broad for all three constructs - some students liked WBLTs while other students disliked them, even when the same WBLT was used by the same teacher. It is worth noting that teachers and students agreed with each other about the learning benefits and design of the WBLTs, but not the engagement value.

Student comments offer a more detailed look at what students liked and did not like when using WBLTs. Students valued using WBLTs because they liked using technology. Many believed that using WBLTs improved the overall learning process. Specific WBLT features that were praised included effective visual supports, ease of use, and interactivity. Features that were criticised include a selection of WBLTs that were either too challenging or not challenging enough, poor organization, and ineffective online help. Students were divided about the overall value of using WBLTs, quality of graphics, theme, and the engagement value of WBLTs. This variation was observed in the survey data.

In spite of the many potential benefits, WBLTs may not be a preferred learning medium for some students. Regardless of preference, teachers need to be careful to select WBLTs that are sufficiently challenging and well-designed with sufficient help features. They must also ensure that the WBLTs provide visual supports, are easy to use, and interactive. Finally, they might want to double-check with students about the potential engagement value before using them in class.

Student Performance

It is clear that learning performance increased when WBLTs were used with post test scores improving by ten to 25 percent. This increase is consistent with previous research (Akpinar & Bal, 2006; Bower, 2005; Kay & Knaack, 2008c; Kong & Kwok, 2005, Liu & Bera, 2005; Nurmi & Jaakkola, 2006; Reimer & Moyer, 2005). The type of questions asked of students after they used a WBLT focussed on remembering facts (50% of all questions), understanding concepts (27%), and applying knowledge (80%). Relatively moderate but significant gains were observed in all three categories. Higher level questions focussing on analysis and evaluation of concepts were asked far less often. This may be due to the fact that the kind of WBLTs used in middle school may target the initial understanding of concepts. One might anticipate that higher level questions would be asked in secondary school.

It would be safe to assume that student performance was directly influenced by 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 used in most lesson plans. Of course one can not make the claim that WBLTs were the only influence on student learning.

Finally, students in this study performed better after using WBLTs regardless of their ability in or attitude toward the subject area where the WBLT was used. This finding suggests that increases in performance due to the use of WBLTs are relatively robust.

Implications for Education

The results of this study lead to several implications for middle school educators who plan to use WBLTs in their classrooms. First, both teacher and students find WBLTs easy to use. Second, most teachers are very positive about the learning impact and added engagement value the WBLTs bring to the classroom. Third, students, while not as positive as teachers, like the visual supports that WBLTs offer and believe that these tools enhance learning. Fourth, the impact of WBLTs may vary greatly within the same classroom. Accommodations may have to be made for students with different ability and interest levels. Finally, teachers need to ensure that WBLTs sufficiently challenge students and are well-designed. WBLTs that are too easy or address concepts already learned appear to turn a number of students off. In addition, WBLTs that are poorly designed and hard to navigate can frustrate students, especially when effective online help is unavailable.

Caveats and Future Research

In this study, a number of steps were taken to ensure high quality data collection and analysis including consistent learning materials, a large sample size, a wide range of well-designed WBLTs selected, and reliable, valid data instruments. Nevertheless, several limitations exist which provide opportunities for future research endeavours. 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 mathematics and science. Different conclusion may be observed in other subject areas.

Second, it is import to acknowledge that students comments made in any one category do not necessarily represent the majority student opinion. The largest number of comments in a single category was 91 (learning) which represents about 20% of the sample population. More often than not, the number of comments made in any one category represented about 10% of the population or less. Therefore, one should be cautious about making general conclusions.

Third, while an attempt was made to explore different types of knowledge gains based on the revised Bloom's taxonomy, more research is needed to determine whether WBLTs can improve higher level knowledge areas such as analysis and evaluation of concepts.

Fourth, while significant gains in learning performance were observed after using WBLTs, the results of this study do not suggest in any way that the use of WBLTs is better than a more traditional method of teaching mathematics or science concepts. A control group would have to be incorporated into the design to evaluate WBLTs relative to other teaching methods.

Finally, while a mixed methods approach was used to assess the impact of WBLTs, the use of think-aloud protocols would be particularly valuable in gaining insight into how WBLTs are used by students. Videotaping students while they are actually using WBLTs might help to provide rich data on the kinds of features that impact student attitudes and learning.

CONCLUSIONS

This study looked at the effectiveness of WBLTs in the middle school environment. The WBLTs for this study were carefully selected and lesson plans were designed based on promising strategies used in previous studies of WBLTs. The results, based on survey data, open-ended questions, and student performance suggest that WBLTs are considered by teacher and students to be well designed, engaging tools that promote learning. Students appreciated the visual supports offered by WBLTs as well as ease of use and interactivity, but bristled at WBLTs that were poorly organized, did not meet their expectations with respect to challenge level, or provided inadequate help. When selected carefully, it appears the WBLTs are a viable medium with which to teach mathematics and science concepts.

References

Agostinho, S., Bennett, S., Lockyear, 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*(2), 191-208. Retrieved from http://www.ascilite.org.au/ajet/ajet20/agostinho.html.

Akpinar, Y., & Hartley, J. R. (1996). Designing interactive learning environments. *Journal of Computer Assisted Learning, 12*(1), 33-46.

Bower, M. (2005). Online assessment feedback: Competitive, individualistic, or…preferred form! *Journal of Computers in Mathematics and Science Teaching, 24*(2)*,* 121-147.

Butson, R. (2003). Learning objects: weapons of mass instruction. *British Journal of Educational Technology*, *34*(*5*), 667-669. doi: 10.1046/j.0007-1013.2003.00359.x

Cohen, J. (1988). *Statistical Power Analysis For The Behavioural Sciences* (2nd edition). New York: Academic Press.

Cohen, J. (1992). A power primer. Psychological Bulletin, *112*(1), 155-159. doi: 10.1037/0033-2909.112.1.155

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:10.1046/j.0007-1013.2003.00359.x

Duval, E., Hodgins, W., Rehak, D., & Robson, R. (2004). Learning objects symposium special issue guest editorial. *Journal of Educational Multimedia and Hypermedia*, *13*(*4*), 331-342.

Gadanidis, G., Gadanidis, J. & Schindler, K. (2003). Factors mediating the use of online applets in the lesson planning of pre-service mathematics teachers. *Journal of Computers in Mathematics and Science Teaching*, *22*(*4*), 323-344.

Haughey, M., & Muirhead, B. (2005). Evaluating learning objects for schools. *Australasian Journal of Educational Technology*, *21*(4), 470-490. Retrieved from http://www.ascilite.org.au/ajet/ajet21/haughey.html

Kay, R. H. (2009a). Appendix A – List of WBLTs used in middle school study. Retrieved from http://faculty.uoit.ca/kay/res/lo/ms.html

Kay, R. H. (2009b). Appendix B – WBLT survey for teachers. Retrieved from http://faculty.uoit.ca/kay/res/lo/ts.pdf

Kay, R. H. (2009c). Appendix C – WBLT survey for students. Retrieved from http://faculty.uoit.ca/kay/res/lo/ss.pdf

Kay, R. H. (2009d). Appendix D – Coding scheme to assess student comments about WBLTs. Retrieved from http://faculty.uoit.ca/kay/res/lo/cs.pdf

Kay, R. H. (2009e). The role of learning objects in distance learning: opportunities and challenges. *In Rogers et al. (Eds.) Encyclopedia of Distance Learning,* 2nd Edition (Volume 2) (pp. 1808-1813). Hershey, PA: Information Science Reference.

Kay, R. H. & Knaack, L. (2008a). A multi-component model for assessing learning objects: The learning object evaluation metric (LOEM). *Australasian Journal of Educational Technology, 24(5)*, 574-591. Retrieved from http://www.ascilite.org.au/ajet/ajet24/kay.pdf

Kay, R. H., & Knaack, L. (2008b). An examination of the impact of learning objects in secondary school. *Journal of Computer Assisted Learning*, *24*(*6*), 447-461. doi: 10.1111/j.1365-2729.2008.00278.x

Kay, R. H. & Knaack, L. (2008c). Exploring the use and effect of learning objects in middle school classrooms. *Canadian Journal of Learning and Technology*, *34*(1), 51-73. Retrieved from http://www.cjlt.ca/index.php/cjlt/article/view/174/170

Kay. R. H., & Knaack, L. (2009). Assessing learning, quality and engagement in learning objects: The learning object evaluation scale for students (LOES-S). *Education Technology Research and Development*, *57*(2), 147-168. . doi: 10.1007/s11423-008-9094-5

Kay. R. H., Knaack, L., & Muirhead, B. (2009). A formative analysis of instructional strategies for using learning objects. *Journal of Interactive Learning Research*, *20*(3), 295-315.

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

Kong, S.C., & Kwok, L.F. (2005). A cognitive tool for teaching the addition/subtraction of common fractions: A model of affordances. *Computers and Education*, *45*(*2*), 245-265. doi:10.1016/j.compedu.2004.12.002

Liu, M. & Bera, S. (2005). An analysis of cognitive tool use patterns in a hypermedia learning environment. *Educational Technology, Research and Development, 53(1),* 5-21. doi: 10.1007/BF02504854

McGreal, R. (2004). Llearning objects: A practical definition. *International Journal of Instructional Technology and Distance Learning, 1*(9). Retrieved from http://www.itdl.org/Journal/Sep_04/article02.htm

Nurmi, S., & Jaakkola, T. (2006). Effectiveness of learning objects in various instructional settings. *Learning, Media, and Technology*, *31*(*3*), 233-247. doi: 10.1080/17439880600893283

Organization for Economic Co-operation and Development (OECD) (2006). *Education at a Glance*. Retrieved from http://mt.educarchile.cl/MT/jjbrunner/archives/libros/OECD_Gl2006/Edu_glance2006.pdf

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

Rehak, D. & Mason, R. (2003). Chapter 3: Keeping the Learning in learning objects. *Journal of Interactive Media in Education*, 2003 (1). Retrieved from http://jime.open.ac.uk/article/2003-1-reuse-05/103

Reimer, K. & Moyer, P.S. (2005). Third-graders learning about fractions using virtual manipulatives: A classroom study. *Journal of Computers in Mathematics and Science Teaching, 24*(1)*,* 5-25.

Sedig, K & Liang, H (2006). Interactivity of visual mathematical representations: Factors affecting learning and cognitive processes. *Journal of Interactive Learning Research. 17*(2), 179-212.

Wiley, D. A. (2000). Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy. In D. A. Wiley (Ed.), The Instructional Use of learning objects: Online Version. Retrieved July, 1, 2005, from http://reusability.org/read/chapters/wiley.doc .

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*(4), 507-521.