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A Formative Analysis of Instructional Strategies for Using Learning Objects

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To date, limited research has been done examining and evaluating the instructional wrap for using learning objects effectively. The current study examined instructional strategies used by 15 teachers to integrate learning objects into 30 secondary school classrooms (510 students). Four key areas were examined: preparation time, purpose for using a learning object, integration strategies, and time spent using a learning object. A small, but significant, correlation was observed between preparation time and student attitudes toward learning objects. When the purpose of using a learning object was to introduce a concept before a formal lesson, motivate students, or teach a new concept, student attitudes and performance were significantly higher. On the other hand, choosing to use a learning object after a formal lesson or to review a concept resulted in significantly lower student attitudes and performance. Regarding integration strategies, providing a guiding set of questions was associated with more positive student attitudes and increased performance, whereas allowing students to explore on their own (without direction) and class discussion after use led to significantly lower student attitudes and performance. Finally, time spent using learning objects was inversely correlated with student attitudes and performance. It is reasonable to conclude that decisions about instructional wrap had a significant impact on the effectiveness of learning objects in a secondary school environment.

Learning objects are operationally defined in this study as interactive web-based tools that support the learning of specific concepts by enhancing, amplifying, and/or guiding the cognitive processes of learners (Bennett &

McGee, 2005; Bradley & Boyle, 2004; Caws, Friesen, & Beaudoin, 2006; Cochrane, 2005; McGreal, 2004; Kay & Knaack, 2007a; Wiley, Waters, Dawson, Lambert, Barclay, & Wade, 2004). One of the first serious discussions about learning objects occurred in the form of an online edited book entitled *The Instructional Use of Learning Objects* (Wiley, 2000). Since that seminal work appeared, numerous papers have been written about learning objects focusing primarily on four key areas: finding an acceptable definition (e.g., McGreal, 2004, Wiley, 2000), design and development (Ally, 2004; Bradley & Boyle, 2004; Kay & Knaack, 2005), storage and retrievable (Agostinho, Bennett, & Lockyear, 2004; Carey, Swallow, & Oldfield, 2002), and reuse (Collis & Strijker, 2004; Koppi, Bogle, & Bogle, 2005). Within the last three years, the scope of research has expanded to three more issues: learning, evaluation, and use (Kay & Knaack, 2007d).

Systematic investigation of instructional strategies used by educators to integrate learning objects into the curriculum has been noticeably absent (Bennett & McGee, 2005; Kay & Knaack, 2007e). One possible reason for this omission is the original paradigm for defining and designing learning objects. A majority of articles, particularly in the domain of higher education, view learning objects as independent, stand-alone, web-based tools (e.g., Kong & Kwok, 2005; Oliver & McLoughlin, 1999; Poldoja, Leinonen, Valjataga, Ellonen, & Priha, 2006). In addition, a number of higher education institutions supported the creation of self-directed objects in an effort to reduce demands on instructor time and save money (Weller, 2004).

However, recent research on the use of learning objects reveals that not all learning objects have a positive impact on learning (Kay & Knaack, 2007c). Nurmi & Jaakola (2006b) suggest that learning objects can facilitate learning through active knowledge construction, although they can also lead to reductionist teaching practices that stress content delivery and knowledge transmission. In fact, several researchers have suggested that teachers need training to maximize the effectiveness of learning objects (Bratina, Hayes, & Blumsack, 2002; COHERE Group, 2002; Gadanidis, Gadanidis & Schindler, 2003; Haughey & Muirhead, 2005). In addition, a growing number of theorists have argued that the ultimate effectiveness of any learning object is largely dependent on the pedagogical choices of the instructor (Alonso, Lopez, Manrique, & Vines, 2005; Bratina et al., 2002; Haughey & Muirhead, 2005; Koppi et al., 2004; McCormick & Li, 2005; Moyer, 2002; Thorpe, Kubiak, & Thorpe, 2003). It appears that while learning objects may have been conceived as autonomous learning tools, how educators use them may be critical to their overall effectiveness.

While a number of papers have focused on the more traditional, self-guided use of learning objects (Docherty, Hoy, Topp, & Trinder, 2005; Kong & Kwok, 2005; Nurmi & Jaakkola, 2006a; Reimer & Moyer, 2005), several studies have looked at the effectiveness of specific strategies used to support learning objects including coaching or facilitating (Liu & Bera, 2005), establishing context (Schoner, Buzza, Harrigan, & Strampel, 2006), instructing students to evaluate their own actions (van Marrienboer & Ayres, 2005), and providing some sort of instructional guide or scaffolding (Brush & Saye, 2001; Concannon, Flynn, & Campbell, 2005; Lim, Lee, & Richards, 2006; Mason, Pegler, &Weller, 2005; Mayer, 2004).

When learning objects were used with minimal interaction from an instructor, moderate success was experienced for higher education students (Docherty et al., 2005; Kong & Kwok, 2005; Reimer & Moyer, 2005). However, students in grades seven to ten did not fair as well (Kay & Knaack, 2007a; Nurmi & Jaakkola, 2006a). It is possible that demands of self-regulation may be too high for younger students. With respect to context, Schoner et al. (2006) noted linking course objectives and learning outcomes to specific learning objects improved educational value. When students were instructed to evaluate their actions, van Marrienboer & Ayres (2005) observed learning objects yielded more positive results. Finally, considerable evidence suggests that learning objects are more effective when scaffolding in the form of worksheets and guiding questions are provided (Brush & Saye, 2001; Concannon et al., 2005; Lim et al., 2006; Mason et al., 2005; Mayer, 2004).

In summary, the agenda for the majority of articles written to date has been to look at the design and developmental process of stand-alone objects that are readily accessed and reused. Only a handful of studies have examined the impact of individual teaching strategies used with learning objects and no studies have compared strategies. However, a substantial number of theorists (Alonso et al., 2005; Bratina et al., 2002; Haughey & Muirhead, 2005; Koppi et al., 2004; McCormick & Li, 2005; Moyer, 2002; Thorpe, Kubiak, & Thorpe, 2003) believe that how a teacher chooses to use a learning object is critical for successful implementation. The purpose of the current study was to examine and evaluate instructional strategies that teachers use when integrating learning objects into secondary school classrooms.

METHOD

Overview

This study reviewed a total of 17 research studies (6 in elementary schools, 2 in secondary schools, 9 in higher education) looking at the impact of specific strategies on the use of learning objects. Many of these studies used mixed methods that included qualitative, quantitative, and performance metrics (n=11); however, a number of challenges remain with respect to improving the investigation of learning objects.

First, while a wide range of learning objects exist, the majority of papers focused on a single learning object. It is difficult to determine whether the results in one study generalize to the full range of learning objects that are available. Second, sample populations tested were relatively small ($M = 65.6$) and poorly described, making it challenging to extend any conclusions to a larger population. Third, while most evaluation studies reported that students benefited from using learning objects, the evidence is based on loosely designed assessment tools with no reliability or validity. Only three out of the 17 studies reviewed offered estimates of reliability (Kay & Knaack, 2007b; Kong & Kwok, 2005; Liu & Bera, 2005), and only one study provided validity data (Kay & Knaack, 2007b). As well, few evaluation studies (e.g., Docherty et al., 2005; Kenny, Andrews, Vignola, Schilz, & Covert, 1999; Kay & Knaack, 2007b; Rieber, Tzeng, & Tribble, 2004; Windschitl & Andre, 1998; Van Zele, Vandaele, Botteldooren, & Lenaerts, 2003) use formal statistics, particularly in the secondary school domain (Kay & Knaack, 2007b).

In order to address key methodological challenges, the following steps were taken:

1. a large, diverse, sample was used
2. reliable and valid surveys were used where possible
3. formal statistics were used when appropriate
4. multiple assessments of impact were used including student perceptions of learning, quality, and engagement with respect to learning objects
5. a measure of student performance was included
6. a wide range of learning objects in a variety of subject areas was tested

Sample

Teachers

The teacher sample consisted of 15 teachers (7 males, 8 females) and 30 classrooms (a number of teachers used learning objects more than once). Teaching experience ranged from 2 to 33 years with a mean of 7.8 (SD = 8.1). Subject areas taught were science (biology, chemistry, general science, physics) and math. A majority of the teachers rated their ability to use computers as strong or very strong (n=14) and their attitude toward using computers as positive or very positive (n=14). In spite of the high ability and positive attitude, only three of the teachers used computers in their classrooms more than once a month.

Students

The student sample consisted of 510 secondary school students (248 males, 262 females), 10 to 22 years of age ($M = 16.5$, $SD = 1.1$). The population base spanned three boards of education, 10 secondary schools, and 30 different classrooms. The students were selected through convenience sampling and had to obtain signed parental permission to participate.

Learning Objects

A majority of teachers selected learning objects from a repository located at the LORDEC website (http://www.education.uoit.ca/lordec/collections.html), although several reported that they also used Google. A total of 16 unique learning objects were selected covering concepts in biology, chemistry, general science, mathematics, and physics (see Appendix A for a complete list of learning objects used).

Procedure

Teachers from three boards of education were asked to volunteer to use learning objects in their classrooms. Each teacher received a half-day of training in November on how to choose, use, and assess learning objects (see http://www.education.uoit.ca/lordec/lo_use.html for more details on the training provided). They were then asked to use at least one learning object in their classrooms by April of the following year. Email support was available throughout the duration of the study. All students in a given teacher's class used the learning object that the teacher selected; only those students with signed parental permission forms were permitted to fill in an anonymous, online survey about their use of the learning object. In addition, students completed a pre- and post-test based on the content of the learning object.

Data Sources

Independent Variables

Four categories of independent variables were used to assess teacher use of learning objects: (1) preparation, (2) purpose, (3) integration, and (4) time spent using the learning object. Preparation referred to the time taken to find an appropriate learning object and to plan its integration into a lesson plan. Purpose included assessing whether learning objects were used to (a) introduce a lesson, (b) motivate students, (c) teach a new concept, (d) review a previous concept, and/or (e) extend a concept. Integration included the following strategies for using the learning objects in a classroom: (a) independent use of computers, (b) introducing the learning object, (c) supports provided for learning object use, and (d) consolidation of a learning object lesson. Time referred to the number of minutes that the learning object component of the lesson took. The coding for each of the independent variables is provided in Appendix A.

It is important to note that teachers could select multiple purposes and integration strategies from the online survey they filled in after using the learning object in their classroom. Sixty-five percent of the teachers (n=19) chose more than one purpose and integration strategy. An attempt was made to find purposes and integration strategies that grouped together using correlation and factor analysis; however, only one consistent pattern was observed. Teachers tended to choose both "introducing a new concept" and "exploring a new concept" together when selecting integration techniques. Therefore, it was decided to analyse individual purpose and integration items.

Dependent Variables

Four dependent variables were chosen for this study: learning, quality, engagement, and student performance. Learning referred to a student's self-assessment of how much a learning object helped them to learn. Quality was determined by student perceptions of the quality of the learning object. Engagement referred to student ratings of how engaging or motivating a learning object was. Student performance was determined by calculating the percent difference between pre-test and post-test created by each teacher based on content of the learning object used in class.

Student self-assessment of learning, quality, and engagement were collected using the Learning Object Evaluation Scale for Students (LOES-S). These constructs were selected based on a detailed review of the learning object literature over the past 10 years (Kay & Knaack, 2007b). According to Kay & Knaack (2007), the LOES-S displayed good reliability, construct validity, convergent validity, and predictive validity. Scale items are presented in Appendix B.

Key Questions & Data Analysis

In order to evaluate teacher use of learning objects with secondary school students, the following questions were addressed in the data analysis:

1. What is the relationship between preparation time for using a learning object and the four dependent variables (learning, quality, engagement, student performance)?
2. How is the intended purpose for using a learning object related to the four dependent variables (learning, quality, engagement, student performance)?
3. How are strategies used to integrate learning objects related to the four dependent variables (learning, quality, engagement, student performance)?
4. Is time spent using a learning object significantly related to the four dependent variables (learning, quality, engagement, student performance)?

RESULTS

Preparation for a Learning Object Lesson

Thirty-one percent (n=9) of the teachers reported that finding a suitable learning object took them less than 30 minutes. Forty-eight percent (n=14) took 30 to 60 minutes to find an appropriate learning object. The remaining 21% (n=6) took over an hour to find the learning object they wanted to use in their class.

With respect to preparation for using the learning object in class, seven percent (n=2) of the teachers spent little or no time, 48% (n=14) spent less than 30 minutes, 35% (n=10) spent 30 to 60 minutes, and the remaining 13% (n=3) spent over an hour.

The time spent finding a learning object was not significantly correlated with student perceptions of learning (r= .03, *n.s.*), quality (r= .00, *n.s.*), and engagement (r= .08, *n.s.*), nor was it correlated with increased student performance (r= .00, *n.s.*). However, time spent on integrating a learning object into a lesson showed small but significant correlations with student perceptions of learning (r= 0.12, $p < .05$), quality (r= 0.13, $p < .01$), and engagement (r= 0.15, $p < .005$), but not with student performance (r= -.08, *n.s.*).

Purpose of Using Learning Object

The most frequent reasons that teachers chose to use learning objects were to review a previous concept (n=16, 55%), motivate students (n=14, 48%), to provide another way of looking at a concept (n=9, 31%), and to introduce or explore a new concept before a lesson (n=7, 24%). Teachers rarely chose to use learning objects to explore a new concept after a lesson (n=2, 7%), teach a new concept (n=1, 3%), or to extend a concept (n=1, 3%).

Introducing a New Lesson

When a teacher decided to use a learning object to "introduce a new topic, then teach a formal lesson," student perceptions of learning (t = -2.17, df =469, $p < .05$) and learning object quality (t = -2.87, df =459, $p < .005$) were significantly higher than when they did not choose this purpose (see Table 1). In addition, student performance was significantly higher ($p < .001$; see Table 2). Assessment of student engagement showed no differences.

If a learning object was used to "explore a new concept before a formal lesson," student perceptions of learning (t = -2.25, df =469, $p < .05$) were significantly higher (Table 1), as was the increase in student performance ($p < .001$; Table 2). Student assessment of learning object quality and engagement showed no differences (see Table 1 below).

Motivating Students

Differences in student perceptions of learning and engagement were not significantly different between teachers who chose to use learning objects as a motivational tool and those who chose not to use it this way (see Table 1). However, learning object quality was rated higher (t = 2.33, df =459, $p < .05$; Table 1) and student performance increased significantly ($p < .005$; Table 2) when one of the main goals for using a learning object was to motivate students.

Table 1
Mean Learning, Quality, and Engagement Scores as a Function of Purpose Chosen by Teachers

Purpose	*Learning* [6]		*Quality* [7]		*Engagement* [8]	
	Yes *M (SD)*	No *M (SD)*	Yes *M (SD)*	No *M (SD)*	Yes *M (SD)*	No *M (SD)*
Introduce first	18.1(3.9)	17.1(4.3) [4]	15.9(3.9)	15.0(4.3) [2]	10.2(3.9)	10.3(4.3) [5]
Explore first	18.0(4.1)	17.1(4.3) [4]	15.4(2.7)	15.2(3.4) [5]	10.2(2.3)	10.3(2.6) [5]
Motivate students	17.4(4.4)	17.3(4.1) [5]	14.8(3.5)	15.5(2.9) [4]	10.1(2.7)	10.4(2.3) [5]
Teach new concept	20.6(3.0)	17.2(4.2) [2]	17.5(1.7)	15.2(3.2) [3]	11.9(1.9)	10.2(2.5) [4]
Another way/method	16.2(4.2)	17.9(4.1) [1]	14.3(3.1)	15.7(3.1) [1]	9.8(2.7)	10.5(2.3) [3]
Review concepts	17.3(4.0)	17.3(4.5) [5]	15.4(3.1)	14.9(3.1) [4]	10.6(2.3)	9.9(2.6) [1]
Explore after	14.3(4.7)	17.6(4.1) [1]	12.1(4.2)	15.5(2.9) [1]	8.5(2.6)	10.5(2.4) [1]
Extend concept	20.0(3.0)	17.2(4.2) [3]	17.5(1.6)	15.1(3.2) [2]	12.0(2.0)	10.2(2.5) [2]

[1] $p < .001$ [2] $p < .005$ [3] $p < .01$ [4] $p < .05$ [5] not significant [6] Possible range is 5 to 25
[7] Possible range is 4 to 20 [8] Possible range is 3 to 15

Table 2
Student Performance as a Function of Purpose Chosen by Teachers

Purpose	*Student Performance Percent Change*		*% Diff*	*df*	*t*
	Yes *M (SD)*	No *M (SD)*			
Introduce first, then lesson	34.7% (28.0%)	15.6% (25.5%)	19.1%	421	-6.68 [1]
Explore first, then lesson	30.5% (26.0%)	16.3% (27.1%)	14.2%	421	-5.07 [1]
Motivate students	26.0% (28.7%)	17.2% (26.0%)	8.8%	421	-3.27 [2]
Teach new concept	50.8% (24.2%)	19.9% (27.1%)	8.8%	421	-3.27 [1]
Another way/method	8.3% (20.9%)	26.0% (28.3%)	-17.7%	421	6.26 [1]
Review concepts	13.5% (22.7%)	29.4% (30.1%)	-15.9%	421	6.16 [1]
Explore after lesson	5.5% (29.6%)	22.1% (27.0%)	-30.9%	421	-3.90 [1]
Extend a concept	11.3% (15.0%)	21.2% (27.9%)	-9.9%	421	1.49 [3]

[1] $p < .001$ [2] $p < .005$ [3] not significant

Teach a New Concept

When a learning object was used to "teach a new concept," student perceptions of learning (t = -2.87, df =469, p < .005), learning object quality (t = -2.73, df =459, p < .01), and engagement (t = -2.59, df =497, p < .05) were higher, and student performance increased significantly (t = -3.90, df =421, p < .001; Table 2).

Review a Previous Concept

When a teacher chose to use a learning object to "provide another way of looking at a concept," student perceptions of learning (t = 3.89, df =469, p < .001), learning object quality (t = 4.42, df =459, p < .001), and engagement (t = 2.82, df =497, p < .01) decreased significantly (Table 1), and student performance was lower (t = 6.26, df =497, p < .001; Table 2).

If a teacher was using a learning object to "review a previous concept," student perceptions of learning and learning object quality were unaffected, engagement (t = -3.3, df =497, p < .001) increased significantly (Table 1), and student performance was significantly lower (t = 6.12, df =421, p < .001; Table 2).

Choosing to use a learning object to "explore a concept after a formal lesson" resulted in lower scores for student perceptions of learning (t = 4.67, df =469, p < .001), learning object quality (t = 6.60, df =459, p < .001), engagement (t = 4.96, df =497, p < .001) (Table 1), and student performance (t = 3.31, df =421, p < .005; Table 2).

Extending a Concept

When a teacher wanted to use a learning object to "extend a concept," student perceptions of learning (p < .01), learning object quality (p < .01), and engagement (p < .005) decreased significantly (Table 1), while student performance was unaffected.

Integration of Learning Object

Almost all teachers (n=28, 97%) chose to have students work independently on their own computers. With respect to introducing the learning object, 62% (n=18) provided a brief introduction and seven percent (n=2) formally demonstrated the learning object. In terms of supports provided, 35% of the teachers (n=10) created a set of guiding questions, while 28% (n=8) provided a worksheet. Thirty-eight percent (n=11) of the teachers chose to discuss the learning object after it had been used.

Independent Use of Learning Object

Choosing to have students work independently on computers as opposed to in pairs or larger groups was not significantly related to student perceptions of learning, learning object quality, and engagement (see Table 3), nor was it related to student performance (see Table 4).

Table 3
Mean Learning, Quality, and Engagement Scores as a Function of Integration Strategys

Purpose	*Learning* [5]		*Quality* [6]		*Engagement* [7]	
	Yes *M (SD)*	No *M (SD)*	Yes *M (SD)*	No *M (SD)*	Yes *M (SD)*	No *M (SD)*
Independent Use	17.3(4.3)	17.7(3.1) [4]	15.1(3.2)	16.4(1.9) [4]	10.3(2.5)	10.0(2.3) [4]
Demonstration	17.8(3.6)	17.3(4.3) [4]	15.1(2.8)	15.3(3.2) [4]	10.2(1.8)	10.3(2.6) [4]
Brief Introduction	17.2(4.3)	17.5(4.0) [4]	15.0(3.3)	15.5(3.0) [4]	10.2(2.5)	10.5(2.5) [4]
Let students explore	16.6(4.2)	17.8(4.1) [2]	14.8(3.6)	15.5(2.9) [3]	10.1(2.6)	10.4(2.4) [4]
Worksheet	18.1(3.7)	17.1(4.4) [3]	15.8(2.5)	15.0(3.4) [3]	10.6(2.5)	10.2(2.5) [4]
Guiding Questions	18.2(3.9)	16.9(4.3) [2]	15.9(2.6)	14.9(3.4) [2]	10.5(2.5)	10.2(2.5) [4]
Discuss After	16.7(4.2)	17.8(4.2) [2]	14.4(3.3)	15.8(2.9) [1]	10.0(2.5)	10.5(2.5) [4]

[1] $p < .001$ [2] $p < .005$ [3] $p < .05$ [4] not significant [5] Possible range is 5 to 25
[6] Possible range is 4 to 20 [7] Possible range is 3 to 15

Table 4
Student Performance as a Function of Integration Strategy

Strategy	*Student Performance Percent Change*		*% Diff*	*df*	*t*
	Yes *M (SD)*	No *M (SD)*			
Independent Use	21.2% (27.8%)	10.5% (15.7%)	10.7%	421	-1.58 [2]
Demonstration	18.4% (24.4%)	21.1% (27.9%)	-2.7%	421	0.63 [2]
Brief Introduction	22.4% (28.8%)	17.9% (25.0%)	4.4%	421	-1.60 [2]
Let students explore	13.6% (25.1%)	24.9% (28.0%)	-11.2%	421	4.10 [1]
Worksheet	20.9% (23.7%)	20.7% (29.0%)	0.2%	421	-0.07 [2]
Guiding Questions	29.1% (26.3%)	15.9% (27.1%)	13.3%	421	-4.92 [1]
Discuss After	14.0% (26.0%)	25.2% (27.6%)	-11.2%	421	4.18 [1]

[1] $p < .001$ [2] not significant

Introduction of Learning Object

Demonstrating a learning object or providing a brief introduction was not significantly related to the four dependent variables used in this study (learning, quality, engagement, student performance) (as shown in Tables 3 & 4). Simply letting students explore on their own was negatively related to student perceptions of learning (t = 2.88, df =469, p < .005) and quality (t = 2.29, df =459, p < .05), but student engagement scores were unaffected (Table 3). Student performance dropped significantly if students were left to explore on their own (Table 4).

Supports Provided

When worksheets were provided, students rated learning (t = -2.29, df = 469, p < .05) and learning object quality (t = -2.27, df =459, p < .05) higher, but not engagement (Table 3). Student performance was unaffected (Table 4). If a teacher created a set of guiding questions, students rated learning (t = -3.23, df = 469, p < .005) and learning object quality (t = -3.33 df =459, p < .005) higher, but not engagement (Table 3). Student performance increased significantly (p < .001; Table 4).

Consolidation

When teachers chose to discuss the learning object after students worked with it, students rated learning (t = -2.71, df = 469, p < .005) and learning object quality (t = -4.65 df =459, p < .001) lower, but not engagement (Table 3). Student performance decreased significantly (p < .001; Table 4).

Time Spent Using the Learning Object

The mean amount of time spent on the learning object component of the lesson was 34.8 minutes (SD = 19.8), with a range of 6 to 75 minutes. Time spent using the learning object was negatively correlated with perceived learning object quality (r= -0.12, p < .01) and student performance (r= -0.12, p < .05). It should be noted that these correlations are quite small.

DISCUSSION

The purpose of this study was to explore and evaluate strategies for using learning objects in secondary school classrooms based on (a) preparation for a learning object lesson, (b) purpose of using learning object, (c) integration of learning object, and (d) time spent using the learning object. Each of these areas will be discussed in turn.

Preparation for a Learning Object Lesson

The time spent to find a suitable learning object ranged from less than 30 minutes to over an hour, with almost 80% of teachers taking less than hour.

However, time directed toward searching for learning objects was not related to students' attitudes or performance. While one might predict that searching for the best learning object should take more time, several other search scenarios may have occurred. It is possible that teachers who took longer to search for learning objects were simply unable to find one that fit their needs. They may have settled for a lower quality learning object simply because they ran out of time. Conversely, teachers who found learning objects quickly might have been impressed by a high-quality learning object early on in the search process.

The majority of teachers spent less than 60 minutes preparing to use learning objects. Unlike search time, preparation time was significantly, but minimally, related to student perceptions of learning, quality, and engagement. However, preparation was not related to student performance. The expectation would be that increased time spent preparing for the use of learning objects would lead to increased success in the classroom; preparation quality may be more important that absolute preparation time. In other words, absolute time spent on preparation may not be as important as learning goals and strategies selected by the teacher.

Purpose of Using Learning Object

Five reasons for using learning objects were evaluated in this study. When a learning object was used to introduce or explore a concept before a formal lesson, student perceptions were more positive and performance increased significantly. This result is partially confounded by the fact that a formal lesson was used in conjunction with a learning object. It is impossible to determine the relative contribution of the learning object to final performance. However, the order in which the learning object is introduced is important. When a learning object was used to explore a concept after a formal lesson, student perceptions, and student performance was significantly lower. It is conceivable that when a learning object is used before a formal lesson, the teacher can build on the experiences of the class and repair any misconceptions, if required. Conversely, if a learning object is used after a formal lesson, students are left to their own devices to make connections and resolve any misconceptions.

Using a learning object to motivate students resulted in favorable student feedback on learning object quality and increased student performance. However, student perceptions of learning and engagement were unaffected. One would expect that if a teacher selected a learning object for motivational reasons, students would be more enthusiastic. This was not the case. There may be disconnect between what teachers and students think is motivating. Furthermore, teachers were allowed to select more than one reason for using a learning object. Other reasons or strategies for using learning objects may have influenced student assessment of engagement value.

While only one teacher chose to use a learning object to teach a new concept without a formal lesson, the impact was positive with respect to student attitudes and performance. It is risky to extrapolate from a sample size of one classroom; however, this may be a strategy that works well. It is speculated that the learning object for this kind of lesson would have to be chosen carefully.

Over 50% of the teachers in this study chose to use learning objects for review purposes, a choice that resulted in lower student attitudes and performance scores. One explanation for this result is that students already knew the material, so differences in pre- and post-test scores were minimal. Furthermore, significantly lower perceptions of learning object quality, engagement, and learning value may reflect student frustration at spending time using technology to review information they already know. Regardless of the possible interpretation of this result, it appears that using learning objects for review purposes with secondary school high school students may not be an effective approach.

Finally, using a learning object to extend a concept, an approach that was used by only one teacher, resulted in negative student attitudes but did not affect student performance. Because of the limited sample size, this result should be treated with caution and needs to be examined in more detail.

Integration Strategies

Four areas of integration were evaluated in this study. First, the decision to have students work independently on computers and not in pairs was made by 97% of the teachers. While there was no difference between student attitude and performance between independent and cooperative use of computers, this result is compromised by disparate sample sizes. In this study, having students work at their own computer appeared to have a neutral influence on attitude and learning outcomes.

Second, providing a brief or extended introduction appeared to be necessary but not sufficient for improving student attitudes and performance. While the type of introduction (brief vs. extended) was unrelated to student perceptions and learning outcomes, post-test scores were significantly lower if students were simply allowed to explore on their own. Paradoxically, students preferred the "explore on your own" approach. In this situation, students' attitudes were not the best predictor of student performance. Some type of introduction and guidance is probably a good starting strategy when using learning objects. This result is consistent with previous research on providing sufficient context (Schoner et al., 2006).

Third, regarding the provision of instruction supports, the results of this study are consistent with previous studies in suggesting that worksheets or guiding questions are essential for the successful use of learning objects (Brush & Saye, 2001; Concannon et al., 2005; Lim et al., 2006; Mason et al., 2005; Mayer, 2004). However, the precise nature of supports appears to be important. When simple worksheets were used, student performance was unaffected, but when guiding questions were offered, student performance increased significantly. Guiding questions may have offered a clearer pathway to the intended goals of the instructor.

Finally, and somewhat surprisingly, consolidation or class discussion after the use of a learning object appears to have a negative effect on student attitude and learning performance. This finding is opposite to what one would expect. One explanation might be that class discussion was used when the use of learning objects did not go smoothly, when there were problems, and perhaps when students experienced confusion. A more detailed description of the discussion is required to fully understand this result.

Time Spent Using the Learning Object

While there was considerable variability in the time spent using learning objects, a significant and negative correlation was observed with respect to perceived learning object quality and student performance. The longer students spent on learning objects, the lower the quality and performance scores. While the magnitude of this correlation was very small, the results may suggest that allowing students to use learning objects without time constraints may be counter productive.

Implications for Education

It is always wise to be cautious with respect to providing educational advice, especially when doing a formative analysis of a topic that has not been systematically evaluated before. However, there are several preliminary suggestions that can be made based on the results of this study. First, while preparation time for the use of learning objects is related to student attitude and performance, it is the specific choices made during this preparation that determine successful learning object implementation. Effective choices made by teachers in this study included using learning objects to motivate students and introduce or explore a concept before a formal lesson, as well as providing guiding questions. Less effective choices involved using learning objects to review concepts and letting students explore on their own without direction. Overall, instructor decisions have a marked impact on the effectiveness of learning objects in a secondary school environment.

Caveats and Future Research

In this study, careful attention was directed toward collecting good quality data by sampling a large, relatively diverse population, establishing the reliability and validity of measures, and using multiple data sources to establish triangulation. Nonetheless, several limitations exist which provide opportunities for future researchers.

First, variability in the kinds of learning objects selected has not been accounted for in this study. Different learning objects may have an impact on the strategies selected by teachers. For example, question and answer learning objects may promote a different learning environment than tool-based learning objects. In addition, specific characteristics of learning objects may have an impact on student perceptions and learning performance, regardless of the instructional strategies chosen. Engaging learning objects with high-quality multimedia may be perceived as more useful than text-based learning objects with limited interactivity. To date, little systematic research has been done examining the qualities of learning objects that promote more effective learning.

Second, student ability was not examined and may have an impact on the success of any learning tool, let alone a learning object. A number of researchers have reported that high ability students may use learning objects differently than low ability students (Akpinar & Bal, 2006; Deaudelin, Dussault, & Brodeur, 2003; Haughey & Muirhead, 2005; van Marrienboer & Ayres, 2005). It is important, then, to investigate these differences with respect to instructional wrap.

Third, while providing guiding questions proved to be a successful strategy, the actual quality of questions was not examined. It is possible that certain kinds of questions are more effective than others in supporting the use of learning objects (Brush & Saye, 2001).

Fourth, more qualitative research is needed to help interpret some of the more puzzling findings reported in this study. It is unclear, for example, why consolidation when using learning objects resulted in lower student performance. A qualitative discussion of what is actually said in the class discussion would help make sense of this counterintuitive result.

Finally, the type of knowledge gains associated with instructional strategies need to be looked at in more detail. The results from this study suggest that certain strategies lead to significant gains in learning performance, but nothing is said about the qualitative nature of knowledge for these gains. For example, Reimer & Moyer (2005) observed increases in conceptual knowledge with learning objects, but not in procedural knowledge.

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APPENDIX A

List of Independent Variables

Variable	Coding
Preparation	
About how long did it take you to find this learning object?	1 – less than 30 minutes 2 – 31 to 60 minutes 3 – 61 to 90 minutes 4 – 91 to 120 minutes 5 – More than 2 hours
Aside from finding the learning object, how much extra time did it take to integrate the learning objects into your lesson?	1 – less than 30 minutes 2 – 31 to 60 minutes 3 – 61 to 90 minutes 4 – 91 to 120 minutes 5 – More than 2 hours
Purpose - What was the main purpose of using your learning object? Check all that apply.	
Introduce a lesson	
Introduce a new topic, then teach a formal lesson	0 = No, 1 = Yes
Explore a new concept before a formal lesson	0 = No, 1 = Yes
Motivate students	
To motivate students about a topic	0 = No, 1 = Yes
Teach a New Concept	
Teach a new concept on its own	0 = No, 1 = Yes
Review a previous concept	
To provide another way of looking at a concept	0 = No, 1 = Yes
Review a previous concept	0 = No, 1 = Yes
Explore a new concept after a formal lesson	0 = No, 1 = Yes
Integration - How did you integrate the learning object into your lesson? Check all that apply.	
Independent Use of Computers	
Students used the learning object on their own computer in class	0 = No, 1 = Yes
Introduce Learning Object	
Did a demonstration of the learning object prior to use	0 = No, 1 = Yes
Provided a brief introduction to the learning object, but did not demonstrate how to use it	0 = No, 1 = Yes
Let the students start exploring the learning object on heir own	0 = No, 1 = Yes
Supports Provided	
Provided a worksheet to support the use of the learning object while they used it	0 = No, 1 = Yes
Provided a set of guiding questions	0 = No, 1 = Yes
Consolidation	
Discussed the learning object after it had been used	0 = No, 1 = Yes
Time - How many minutes did the learning object component of the lesson take?	Open ended

APPENDIX B

Learning Object Evaluation Survey - Students

	Strongly Disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly Agree 5
Learning					
1. Working with the learning object helped me learn.	1	2	3	4	5
2. The feedback from the learning object helped me learn.	1	2	3	4	5
3. The graphics and animations from the learning object helped me learn.	1	2	3	4	5
4. The learning object helped teach me a new concept.	1	2	3	4	5
5. Overall, the learning object helped me learn.	1	2	3	4	5
Quality					
6. The help features in the learning object were useful.	1	2	3	4	5
7. The instructions in the learning object were easy to follow.	1	2	3	4	5
8. The learning object was easy to use.	1	2	3	4	5
9. The learning object was well organized.	1	2	3	4	5
Engagement	1	2	3	4	5
10. I liked the overall theme of the learning object.	1	2	3	4	5
11. I found the learning object motivating.	1	2	3	4	5
12. I would like to use the learning object again.	1	2	3	4	5

APPENDIX C

List of Learning Objects Used in the Study

Collection	Name of Learning Object	Web Address	Status
NLVM	Algebra Balance Scales	http://nlvm.usu.edu/en/nav/frames_asid_201_g_4_t_2.html?open=instructions	Open
TLF	Alpha, Beta, Gamma of Radiation	http://www.thelearningfederation.edu.au/tlf2/	Closed
Learn Alberta	Ammeters and Voltmeters	http://www.learnalberta.ca/	Closed
UOIT	Capillary Fluid Exchange	http://education.uoit.ca/EN/main/151820/151827/research_teach_locollection.php	Open
FunBased	Classic Chembalancer	http://funbasedlearning.com/chemistry/chemBalancer/	Open
Independent	Congruent Triangles	http://argyll.epsb.ca/jreed/math9/strand3/3203.htm	Open
PHET	Energy Skate Park	http://phet.colorado.edu/simulations/energyconservation/energyconservation.jnlp	Open
DNA Int	Gel electrophoresis	http://www.dnai.org/b/index.html	Open
Shodor	Maze Game	http://www.shodor.org/interactivate/	Open
Independent	Metals in Aqueous Solutions	http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/animationsindex.htm	Open
Learn Alberta	Multiplying and Dividing Cells	http://www.learnalberta.ca/	Closed
WISC Online	Periodic Table	http://www.wisc-online.com/objects/index_tj.asp?objid=SCI202	Open
TLF	Reading Between the Lines	http://education.uoit.ca/lordec/lo/L80/LV5536/	Open
PBS	Structure of Metals	http://www.pbs.org/wgbh/nova/wtc/metal.html	Open
UOIT	Transformation of Parabola	http://education.uoit.ca/EN/main/151820/151827/research_teach_locollection.php	Open
UW Madison	Wild Weather	http://cimss.ssec.wisc.edu/satmet/modules/wild_weather/index.html	Open