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An examination of the impact of learning objects in secondary school

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Abstract Very few studies have systematically evaluated the effect of learning objects in secondary school classrooms. The vast majority of studies have focussed on higher education. The current study examined the impact of learning objects from the perspective of 850 students and 27 teachers (50 classrooms) of science, mathematics, or social science. The results suggest that teachers typically spend 1 to 2 h finding and preparing for learning object based lesson plans that focus on the review of previous concepts. Both teachers and students are positive about the learning benefits, quality, and engagement value of learning objects, although teachers are more positive than students. Student performance increased significantly – almost 30% – when learning objects were used in conjunction with a variety of teaching strategies. It is reasonable to conclude that learning objects are a viable teaching tool in a secondary school environment.

Keywords assess, evaluate, learning object, quality, secondary school.

Examining the impact of learning objects in secondary school

Overview

The design, development, reuse and accessibility of learning objects has been examined in some detail for almost 10 years (Kay & Knaack 2007b). However, research on the effectiveness and usefulness of learning objects is limited (Sosteric & Hesemeier 2002; Kay & Knaack 2005; Nurmi & Jaakkola 2005, 2006a,b). Until recently, learning objects were solely used in higher education (Haughey & Muirhead 2005; Kay & Knaack 2005, 2007b). The purpose of the current study is to examine the impact of learning objects in secondary school classrooms.

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Literature review

Benefit of using learning objects

Learning objects, defined in this article as 'interactive Web-based tools that support learning by enhancing, amplifying, and guiding the cognitive processes of learners' (Butson 2003; Polsani 2003; Agostinho *et al.* 2004; McGreal 2004; Parrish 2004; Wiley *et al.* 2004) offer a number of advantages for educators and students including accessibility (Wiley 2000), ease of use (e.g. Gadanidis *et al.* 2003; Sedig & Liang 2006), reusability (e.g. Rehak & Mason 2003; Agostinho *et al.* 2004; Duval *et al.* 2004), interactivity (e.g. Gadanidis *et al.* 2003; Sedig & Liang 2006) and visual supports (e.g. Gadanidis *et al.* 2003; Sedig & Liang 2006).

In spite of this list of potential benefits, little systematic research has been done examining the actual use and impact of learning objects in the classroom (Kenny *et al.* 1999; Van Zele *et al.* 2003; Bradley & Boyle 2004).

Impact of learning objects in higher education

Eighteen articles were reviewed for this study, looking at the use of learning objects in higher education. Five studies examined faculty attitudes, 11 explored student attitudes and seven assessed student performance. A meta-analysis of these studies was not possible given that 15 of the papers reviewed relied on informal qualitative evidence.

Faculty perspective

With respect to attitudes towards learning objects, higher education faculty reported that there were at least three obstacles. First, the faculty did not have sufficient awareness and understanding of learning objects to determine teaching advantages (Collis & Strijker 2003; Shea *et al.* 2006). Second, it was anticipated that the time required to integrate learning objects into an existing course or curriculum would be prohibitive (Collis & Strijker 2003; Koppi *et al.* 2004). Finally, the time needed to find good learning objects was deemed to be extensive (Collis & Strijker 2003; Christiansen & Anderson 2004).

Only two studies assessed teacher attitudes towards actually using learning objects in a real classroom (Bradley & Boyle 2004; De Salas & Ellis 2006). In the first study, teachers were informally polled and reported that learning objects complimented the course textbook well (Bradley & Boyle 2004). In the second study, the general perception was that learning objects helped students be more engaged and better prepared for class (De Salas & Ellis 2006).

Student perspective

Regarding perceptions of learning objects, undergraduate or graduate students had positive attitudes about learning objects in eight studies (Kenny *et al.* 1999; Bradley & Boyle 2004; Docherty *et al.* 2005; MacDonald *et al.* 2005; Mason *et al.* 2005; Schoner *et al.* 2005; De Salas & Ellis 2006; Lim *et al.* 2006), neutral attitudes in one study (Concannon *et al.* 2005) and negative attitudes in one study (Van Zele *et al.* 2003). Most papers offered informal or qualitative evidence, while three studies reported that approximately 50% to 60% of higher education students liked using learning objects (Howard-Rose & Harrigan 2003; Bradley & Boyle 2004; De Salas & Ellis 2006).

Students offered positive comments about a wide range of characteristics including animations (Bradley & Boyle 2004), self-assessment (Lim *et al.* 2006), attractiveness (Bradley & Boyle 2004), control over learning (Lim *et al.* 2006), ease of use (Kenny *et al.* 1999; Schoner *et al.* 2005), feedback (Concannon *et al.* 2005; Lim *et al.* 2006), scaffolding or support (Lim *et al.* 2006), interactivity (Concannon *et al.* 2005; Lim *et al.* 2006), navigation (Concannon *et al.* 2005) and self-efficacy (Docherty *et al.* 2005). Negative comments focussed on problems with navigation (Concannon *et al.* 2005), technology (Concannon *et al.* 2005) and workload (Van Zele *et al.* 2003).

Student performance

Regarding student performance, three studies offered qualitative evidence that student learning performance improved when learning objects were used (Windschitl & Andre 1998; Kenny *et al.* 1999; Lim *et al.* 2006). Two studies offered descriptive evidence suggesting that learning objects enhanced student learning (Bradley & Boyle 2004; MacDonald *et al.* 2005). MacDonald *et al.* (2005) reported fewer students having to make major changes on their assignments and Bradley and Boyle (2004) observed pass rates increasing by 12% to 23%. Three papers presented formal statistical analyses with respect to student performance and the use of learning objects (Windschitl & Andre 1998; Rieber *et al.* 2004; Docherty *et al.* 2005). Docherty *et al.* (2005) reported that nursing students were significantly more positive about learning objects than control groups, but the marks on the final course were not significantly different. Rieber *et al.* (2004) observed that students, provided with embedded explanations and graphical representations, performed significantly better than those students who did not receive these supports. Finally, Windschitl and Andre (1998) noted that simulation-based learning objects showed significant gains in two out of six concepts taught. The remaining four concepts showed no significant difference.

Use of learning objects in secondary school

Only four published studies were found investigating the use of learning objects with secondary school students (Brush & Saye 2001; McCormick & Li 2005; Kay & Knaack 2007b; Lopez-Morteo & Lopez 2007).

Teacher perspective

Two studies looked at how teachers viewed learning objects (McCormick & Li 2005; Kay & Knaack 2007b). Kay and Knaack (2007b) reported preservice and experienced teachers strongly agreed that

- learning objects were a beneficial tool for students.
- they helped students with respect to understanding concepts.
- they would be interested in using the learning objects in their classrooms again.

McCormick and Li (2005) noted that 60% to 75% of teachers felt learning objects were useful and enjoyed using learning objects, although over 50% reported technical problems local to their schools.

Student perspective

Brush and Saye (2001) observed that students tended to look at superficial content in a learning object when left to their own devices and that more active guidance and structure was needed when using information-based learning objects. Kay and Knaack (2007b) used a comprehensive assessment measure and reported that students were moderately positive about learning objects. In addition, overall usefulness, clear instructions, organized layout and good theme/motivation were particularly important to students. Finally, Lopez-Morteo and Lopez (2007) reported that students perceived interactive, recreation-based, collaborative learning objects positively.

Student performance

To date, no studies have been done looking at the impact of learning objects on the performance of secondary school students.

Methodological issues

This study looked at a total of 22 articles (18 in higher education, four in secondary schools). Several good quality studies have been performed. Ten studies incorporated mixed methods, which included qualitative, quantitative and performance metrics. Six studies had sample populations of over 100. Nonetheless, a number of challenges remain with respect to improving the investigation of learning objects, particularly in secondary schools.

First, only four studies have been done examining the use of learning objects outside the higher education populace. Learning objects were originally targeted at tertiary education, and use in secondary schools requires further analysis. Second, there is inadequate data on how teachers react to and use learning objects in a real world situation. Only four of the 22 studies reviewed examined teacher perspectives on the actual use of learning objects (Bradley & Boyle 2004; McCormick & Li 2005; De Salas & Ellis 2006; Kay & Knaack 2007b).

Third, even though a wide range of learning objects exist, the majority of papers focus on a single learning object (e.g. Kenny *et al.* 1999; Bradley & Boyle 2004; Krauss & Ally 2005; MacDonald *et al.* 2005). It is difficult to determine whether the evaluation tools used in one study generalize to the full range of learning objects that are available.

Fourth, sample populations tested in many studies are relatively small and poorly described (e.g. Van Zele *et al.* 2003; Krauss & Ally 2005; MacDonald *et al.* 2005) making it challenging to extend any conclusions to a larger population. This observation is more evident in secondary school studies where only one paper looked at more than 70 students (Kay & Knaack 2007b).

Fifth, while triangulation of data collection has been achieved in a number of studies by using multiple data collection tools (e.g. Howard-Rose & Harrigan 2003; Van Zele *et al.* 2003; Docherty *et al.* 2005; Schoner *et al.* 2005) only four studies have looked at both student and teacher perspectives at the same time (Bradley & Boyle 2004; McCormick & Li 2005; De Salas & Ellis 2006; Kay & Knaack 2007b). No studies have examined student attitude, teacher attitude and student performance simultaneously.

Sixth, 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 (e.g. Kenny *et al.* 1999; Howard-Rose & Harrigan 2003; Van Zele *et al.* 2003; Bradley & Boyle 2004; Krauss & Ally 2005; Schoner *et al.* 2005; Lopez-Morteo & Lopez 2007). Only two out of the 22 studies reviewed offered estimates of reliability (Windschitl & Andre 1998; Kay & Knaack 2007b) and one study provided data validity (Kay & Knaack 2007b). As well, few evaluation studies (e.g. Windschitl & Andre 1998; Kenny *et al.* 1999; Van Zele *et al.* 2003; Rieber *et al.* 2004;

Docherty *et al.* 2005; Kay & Knaack 2007b) used formal statistics, particularly in the secondary school domain (Kay & Knaack 2007b). The lack of reliable and valid evaluation tools combined with an absence of statistical rigour reduce confidence in the results presented to date.

Finally, a promising trend in learning object evaluation research is the inclusion of performance measures (e.g. Bradley & Boyle 2004; Docherty *et al.* 2005; MacDonald *et al.* 2005). Until recently, there has been little evidence to support the usefulness or pedagogical impact of learning objects. The next step is to refine current evaluation tools to determine which specific qualities of learning objects influence performance.

In summary, previous methods used to evaluate learning objects have offered extensive descriptive and anecdotal evaluations of single learning objects, but are limited with respect to sample size, representative populations, reliability and validity of data collection tools and the use of formal statistics. Recent evaluation efforts to incorporate learning performance should be encouraged in order to advance knowledge of learning object features that may influence learning.

Purpose

The purpose of this study was to examine the impact of learning objects in secondary schools. With respect to impact, teacher and student perceptions of quality, engagement and learning were assessed, as well as student learning performance.

Method

Overview

In order to address the key methodological challenges noted in previous evaluation of learning objects, the following steps were taken:

1. A large, diverse, sample was used.
2. Reliability and valid surveys were used.
3. Formal statistics were used where applicable.
4. Both qualitative and quantitative data were collected.
5. Both teacher and student perspectives were assessed.
6. A measure of student performance was included.
7. A wide range of learning objects in a variety of subject areas was tested.

Sample

Teachers

The teacher sample consisted of 27 teachers (12 males, 15 females) and 50 classrooms (a number of teachers used learning objects more than once). Teaching experience ranged from 1 to 33 years with a mean of 9.2 (SD = 8.2). Subject areas taught were science (biology, chemistry, general science, physics, $n = 15$), math ($n = 10$) and social science (geography, history, $n = 2$). Eighty-five percent of the teachers rated their ability to use computers as strong or very strong and their attitude towards using computers as positive or very positive. However, only six of the teachers used computers in their classrooms more than once a month.

Students

The student sample consisted of 850 secondary school students (444 males, 406 females) ranging in age from 10 to 22 years (M = 16.5, SD = 1.1). The population base spanned three separate boards of education, 15 secondary schools and 27 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 (Learning Object Research Development and Evaluation Collaboratory; http://www.education.uoit.ca/lordec/collections.html), although several reported that they also used Google. A total of 33 unique learning objects were selected covering concepts in biology, chemistry, general science, geography, mathematics and physics.

Procedure

Teachers from three boards of education volunteered to use learning objects in their classrooms. Each teacher received a half day of training in November 2006 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 2007 of the following year. E-mail 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. However, 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

Teacher use
Teachers were asked

1 how long it took them to find and integrate learning objects into their classroom;
2 their purpose for using the learning object (e.g. motivate students, teach a new concept, review, supplementing a lesson); and
3 strategies they used to integrate learning objects (e.g. demonstration, providing a set of guiding questions, let student explore, discussion after learning object).

Teacher survey
Each teacher completed the Learning Object Evaluation Scale for Teachers (LOES-T – see Appendix A) to determine their perception of how much their students learned (learning construct), the quality of the learning object (quality construct) and how much their students were engaged with the learning object (engagement construct). The constructs selected were based on a thorough review of the literature (Kay & Knaack 2005, 2007b). The LOES-T showed fair to moderate reliability and good construct validity (see Kay & Knaack 2007c).

Teacher comments
Finally, teachers were asked to comment on the overall impact that the learning object had on learning (question 9, Appendix A).

Student survey
After using a learning object, students completed the Learning Object Evaluation Scale for Students (LOES-S) in Appendix B to determine their perception of how much they had learned (learning construct), the quality of the learning object (quality construct) and how much they were engaged with the learning object (engagement construct). The constructs selected were based on a thorough review of the literature (Kay & Knaack 2005, 2007a,b,c). The scale showed good reliability (0.78 to 0.89), face validity, construct validity, convergent validity and predictive validity (see Kay & Knaack 2007a).

Student comments
Students were asked to comment on what they liked and disliked about the learning object (Appendix B – questions 13 and 14). These qualitative items were organized according to the three main constructs identified in the literature review (learning, quality and engagement) and analysed using the coding scheme provided in Table 1. This coding scheme (Kay & Knaack 2007a) was used to categorize 1302 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 achieved inter-rater reliability of 99% on the categories and 100% on the 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, from Table 2, the impact of visual supports on learning was calculated by multiplying the mean which was 0.91 by the number of students who commented about visual supports (92) for a total of 84.0.

Student performance
Students completed a pre- and post-test based on the content of the learning object used in class. The difference between pre- and post-test scores was used to determine student performance.

Key questions and data analysis

In order to examine the impact of learning objects on secondary school students, the following questions were addressed in the data analysis:

- How do teachers use learning objects in their classrooms? (descriptive analysis of teacher-use questions)
- How do teachers rate learning, quality and engagement of learning objects? (descriptive analysis of teacher survey – LOES-T)
- What was the overall impact of learning objects? (analysis of qualitative teacher comments)
- How do students rate learning, quality and engagement of learning objects? (descriptive analysis of student survey – LOES-S)

Table 1. Coding scheme to categorize student comments about learning objects.

(a) Learning

Category label	Criteria
Challenge	Refers to the ease/difficulty of the concepts being covered. Basically whether the content level of the LO matched the student's cognitive level/understanding. Code 'it was easy' in here, but not 'it was easy to use'
Learn	Student comments about a specific or general learning/teaching issue involved in using the LO
Visual	The student mention as visual feature of the LO that helped/inhibited their learning

(b) Engagement

Category label	Criteria
Compare	Student compares LO to another method of learning
Engage	Student refers to program as being OR not being fun/enjoyable/engaging/interesting
Technology	The student mention a technological issue with respect to using the LO

(c) Quality

Category label	Criteria
Animate	Refers to quality of animations/moving pictures
Audio	Refers to some audio/sound aspect of the learning object
Easy	Refers to clarity of instructions or how easy/hard the LO was to use. It does not refer to how easy/hard the concept was to learn.
Graphics	Refers to static picture or look of the program (e.g. colours)
Help	Refers specifically to help/hints/instructions/feedback provided by the LO
Interactive	Student refers to some interactive part feature of the LO
Control	Refers to student control of choice/pace in using the LO
Organization/design	Refers to quality of organization/design or the LO
Text	Refers to quality/amount of text in LO
Theme	Refers to overall/general theme or CONTENT of LO

LO, learning object.

- What do students like and dislike most about learning objects? (qualitative analysis of student comments)
- How do teacher ratings of learning objects compare with student ratings? (correlation among learning, quality and engagement constructs)
- How do learning objects affect student performance (*t*-test comparing pre and post scores)?

Results

Use of learning objects

Finding a learning object

Forty-two percent of the teachers reported that finding a suitable learning object took them less than 30 min. Thirty-six percent took 30 to 60 min to find an appropriate learning object. The remaining 22% took over an hour to finding the learning object they wanted to use in their class.

Preparing a learning object lesson

With respect to preparation for using the learning object in class, 6% of the teachers spent little or no time, 42% spent less than 30 min, 28% spent 30 to 60 min and the remaining 24% spent over an hour.

Using a learning object

On average, teachers used learning objects for 38.1 min (SD = 30.5). However there was considerable variability (6 to 210 min). Students worked independently on their

Table 2. Summary of student comments about learning objects.

Category	Mean	SD	*n*	Total effect (mean × *n*)
Learning				
Visual supports	0.91	0.41	92	84.0
Overall learning	–0.07	1.11	191	–13.0
Challenge	–0.48	1.04	152	–73.0
Quality				
Easy	0.95	0.60	74	70.0
Animation	0.67	0.75	43	29.0
Graphics	0.24	1.08	97	23.0
Audio	–1.00	0.00	5	–5.0
Theme	–0.19	1.22	42	–8.0
Control	–0.32	1.04	34	–11.0
Organization	–0.25	1.11	55	–14.0
Help	–0.53	1.00	68	–36.0
Text	–1.03	0.59	38	–39.0
Engagement				
Interactivity	0.79	0.71	73	58.0
Compare with other method	0.70	0.75	63	44.0
Engagement/motivation	0.21	1.16	107	22.0
Liking technology	–0.10	1.21	59	–6.0

Table 3. Teacher rating of learning, quality, and engagement for learning objects.

Scale	No. of items	Possible range	Actual range observed	Mean (SD)
Learn	2	2 to 14	8 to 14	11.4 (1.4)
Quality	3	3 to 21	11 to 21	17.3 (2.6)
Engagement	3	2 to 21	9 to 21	17.1 (2.9)

own computers in a majority of classrooms (90%), with cooperative learning chosen only 10% of the time.

Reason for using a learning object

The top four reasons cited by teachers for using learning objects was to review a previous concept (54%), to provide another way to look at a concept (48%), to motivate students about a topic (38%) and to introduce a concept before a formal lesson (30%). Teachers rarely used learning objects to teach a new concept (8%), explore a new concept after a formal lesson (6%) or for homework (4%).

Strategies for using learning objects

Teachers in this study typically provided a brief introduction to a learning object (58%) or let the students start exploring on their own (46%). Only 16% offered a formal demonstration of the learning object before the class used it. Forty percent of teachers prepared a formal handout for students to guide the use of the learning object. Thirty-eight percent of teachers chose to have a class discussion about the learning object after it was used by students.

Teacher rating of learning objects

Learning

The mean rating for the learning construct was 11.4 (SD = 1.4) or 5.7 on a 7-point scale. This suggests that most teachers agreed that learning objects had a positive impact on student learning. Note that the range of learning construct scores was relatively narrow (8 to 14) providing additional support for the conclusion that a majority of teachers felt learning objects offered learning benefits (Table 3).

Quality of learning object

The mean rating of learning object quality was 17.3 (SD = 1.4) or 5.8 on a 7-point scale. Most teachers agreed or strongly agreed the learning object was of

Table 4. Qualitative comments from teachers.

Category	*n*	%	Sample comments
Learning			
Overall positive	12	18%	'It was a success, and I think it helped students prepare for an upcoming lab on the topic.'
			'Students had a much better background in the subject when it was introduced [using learning objects]'
			'[The learning object] kept them on task and the class basically ran itself'
Overall negative	4	5%	'They still had great difficulty distinguishing between vertical and horizontal stretches and compressions.'
			'The method of explanation and some of the wording was different than our . . . textbook'
Visual supports	15	22%	'I feel like the visual . . . interaction with the stages of mitosis really helps them to understand the basic concepts of cell division'
			'They had not been very good at solving problems like this earlier in the semester. The graph that it drew to show the relationship helped them a lot'
			'For many students, using the balance scale was an excellent visual representation of solving algebra problems.'
Review	12	18%	'It helped review a topic that I had taught them last year in grade 11'
			'This learning object was a great interactive review of concepts learned in grade 6. It not only helped review concepts, but it also motivated students about probability (the topic of our new unit)'
			'I am always reviewing balancing equations, and this learning object provided [the] students with an interactive and immediate means to assess what they remembered.'
Interactive	4	6%	'The interactivity of the learning object helped the students view the relationships between the sizes of the different objects.'
Engagement	15	22%	'It helped to motivate them during the formal teaching after the learning object.'
			'Most students seemed to enjoy working with the learning object'
Time	9	13%	'The learning object allowed me to take a much shorter time to teach to teach the concept'
			'I had only had one class prior to using the learning object to introduce the concept to the class because of problems at the school in terms of booking computer time.'
Individual differences	2	3%	'Some students seemed to work well, however, one student was finished in 5 minutes, whilst another was finished in 35 minutes'
			'The learning object was a good one, but only my strongest students were able to learn the concept using the learning object and accompanying worksheets.'

good quality. The range of learning object quality scores was broader than the learning construct scores (11 to 21) but never dipped into negative rating (Table 3).

Engagement

Teachers also rated engagement with learning objects high with a mean score of 17.1 (SD = 1.4) or 5.7 on a 7-point scale. A majority of teachers, then, felt students were engaged while using learning objects. The range of learning object engagement scores was relatively large compared to the learning and quality constructs (9 to 21) (Table 3).

Teacher comments about learning objects

Four themes emerged from the 68 comments that teachers made about the overall impact of the learning object: learning (63%), engagement (22%), time (13%) and individual differences (3%). Details for each theme and sample comments offered by teachers are presented in Table 4.

Of the 43 comments that teachers made about learning, 12 focussed on overall impact. Eight teachers made positive comments about how much was learned or how students were on task. However, four teachers observed that the learning object was not as successful as they had hoped. Twelve teachers commented on the effectiveness

Table 5. Description of Student Learning Object Evaluation Scales.

Scale	No. of items	Possible range	Actual range observed	Mean (SD)
Learn	5	5 to 25	5 to 25	17.0 (4.3)
Quality	4	4 to 20	4 to 20	14.9 (3.3)
Engagement	3	3 to 15	3 to 15	10.2 (2.6)

of learning objects to provide a good review and 15 teachers noted that visual supports provided good opportunities for learning. Finally, four teachers remarked that learning objects provided good interactivity for the students.

Almost one quarter of the teachers felt that one of the key impacts of learning objects was engagement. They believed that students were more interested or motivated when using this tool. Nine teachers mentioned that time was an issue either in creating a good lesson plan with a learning object, saving time, booking the right time to use a learning object or not having enough time. Finally, three teachers observed individual differences with respect to the impact of learning objects. Some students worked with learning objects quickly and efficiently whereas others struggled and took more time.

Student rating of learning objects

Learning

Students rated learning objects lower than teachers with respect to learning (M = 17.01, SD = 4.3) with a mean item rating of 3.4 out 5 (or 4.8 out of 7). Students were between 'neutral' and 'agree' with respect to how much they felt the learning objects contributed to their learning. The range of scores was extensive (5 to 25), indicating that there was considerable variability (Table 5). The mean range was 13.5 (SD = 3.9) out of a possible 20-point spread.

Quality of learning objects

Students rated the quality of learning objects higher than the learning construct, although the mean item rating was still lower than that of the teachers. The mean item rating of 3.7 out of 5 (5.2 out of 7) indicated that most students agreed that the learning objects they used were of good quality. The range of learning object quality scores (4 to 20) showed considerable variability (Table 5). The mean range was 9.2 (SD = 3.3) out of a possible 16-point spread.

Engagement

Ratings of learning object engagement were moderate (M = 10.2, SD = 2.6) with a mean item rating of 3.4 out or 5 (or 4.8 out of 7). In other words, as was the case with the learning construct, students were somewhere in between 'neutral' and 'agree' when assessing the engagement value of the learning objects they used. High variability among student engagement ratings is supported by the wide range of scores reported (3 to 15) and a mean range of 8.3 (SD = 2.5) out of a possible 12 point spread.

Student comments about learning objects

Student comments are summarized in Table 2. With respect to learning, the visual support that a learning object offered towards learning was rated the highest, whereas the pedagogical challenge of learning objects was rated quite low. In other words, many students liked the visual affordances of learning objects. However, quite a few felt the learning object was not challenging enough.

With respect to rating the quality of learning objects, ease of use was the highest rated feature, followed by animation and graphics. The quality of help and the excessive amount of text was rated the lowest.

Finally, regarding engagement, 'interactivity' and 'comparing learning objects to other methods of teaching' were rated highest. A number of the students liked the interactive qualities of learning objects and felt they were an improvement over other teaching strategies.

Teacher vs. student ratings

Teacher ratings of learning ($r = 0.51$, $P < 0.001$), quality ($r = 0.52$, $P < 0.001$) and engagement ($r = 0.39$, $P < 0.001$) were significantly correlated with student ratings of the same constructs. Note that the teachers and students did not appear to agree on the engagement construct as much as they did on the learning and quality constructs.

Student performance

Differences between pre- and post-test scores were calculated for classes where the learning object was not used for review. This yielded a total of 194 students. Student performance scores increased by an average of 29.3% from 40.5% to 69.9%. This change was significant ($t = -13.6$, d.f. = 193, $P < 0.001$). The effect size (based on Cohen's d) of 1.10 is considered very large according to Thalheimer and Cook (2002).

Discussion

The purpose of this study was to examine the impact of learning objects in secondary school classrooms. Six sources of data were examined: teacher use, teacher ratings, teacher comments about overall impact, student ratings, student comments about what they liked and did not like and student performance. Each of these data sources will be discussed in turn.

Teacher use

Previous research is relatively silent with respect to how teachers use computers. This study provides new information in this area. On the surface, it appears that finding and preparing to use a learning object for a secondary school classroom does not take excessive time – roughly an hour on average. However, a number of teachers commented that time was an issue in using learning objects. While an hour is not overwhelming in terms of time, it may be more than the typical teacher spends on a regular lesson plan.

It is interesting that most teachers used learning objects to support concepts that they had already taught. Only 30% used learning objects to help teach a new topic before a formal lesson and less than 10% used learning objects to teach a new concept on its own. One could speculate that teachers were being cautious with respect to introducing a new teaching strategy in their classroom.

When using learning objects, most teachers offered a brief introduction and let the students explore on their own. About 40% of teachers prepared a formal handout and/or had a class discussion about the learning object. This meant that the majority of teachers did not provide scaffolding – students were left to investigate and draw conclusions on their own. Perhaps teachers felt that since the concept being covered was a review, there was no need to provide additional support. It might also mean that teachers felt that the learning objects they selected should stand on their own in terms of teaching.

Teacher ratings and comments (learning, quality and engagement)

It is safe to say that teachers felt that the learning objects they selected were good quality engaging tools that supported learning. Ratings were very high. On the one hand, it is somewhat predictable that teachers would rate learning objects high – after all they were the ones who selected them. On the other hand, teachers rated these learning objects after they watched them being used by students in their classroom. The fact that teacher ratings were relatively consistent with student ratings partially confirms reliability and validity. Positive reaction from teachers in this study is consistent with previous research on secondary education teachers and learning objects (McCormick & Li 2005; Kay & Knaack 2007b).

Teacher comments

With respect to learning, teacher comments were consistent with the survey results. Most teachers felt their students were on task and that the learning objects offered a good review of concepts. In addition, learning objects were thought to be engaging. These comments are reflective of previous findings (De Salas & Ellis 2006; Kay & Knaack 2007b). A smaller group of teachers reported that time was a concern – an issue that worried higher education faculty (Collis & Strijker 2003; Christiansen & Anderson 2004). Finally, three teachers reported that they noticed individual differences with respect to students' interaction with learning objects in terms of pace and ease of use. Clearly the results from this small sample should be treated cautiously, although it may be worthwhile to explore individual differences in future studies.

Student ratings (learning, quality and engagement)

Students were moderately positive about the quality and engagement of learning objects and closer to neutral

when assessing the learning value. These results somewhat contradict more positive findings reported for higher education (Kenny *et al.* 1999; Bradley & Boyle 2004; Docherty *et al.* 2005; MacDonald *et al.* 2005; Mason *et al.* 2005; Schoner *et al.* 2005; De Salas & Ellis 2006; Lim *et al.* 2006). However, when quantitative data is gathered (e.g. Howard-Rose & Harrigan 2003; Bradley & Boyle 2004; De Salas & Ellis 2006), students' satisfaction with learning objects hovers around 50%–60%. In addition, the results of this study match those reported by Kay and Knaack (2007b) who observed that students were 'somewhat positive' when rating learning objects.

It is worth noting that the range of scores is broad for all three constructs. This means that for any given learning object, some students like it a lot and others dislike it a lot, even when it is the same learning object and the same teacher. As stated earlier, some teachers noted individual differences in the use and acceptance of learning objects. The age old problem of trying to address diversity in needs and ability still exists when learning objects are used.

Student comments about learning objects

Student comments offer some insights into why students liked and did not like using learning objects. Students liked learning objects that were easy to use and had good interactivity, visual supports, animations and graphics. They did not like learning objects that were not challenging enough, nor did they like poor help features and excessive amounts of text. These findings are closely aligned to the results reported by Kay and Knaack (2007b). It is also worth noting that even though a good number of students may not have rated learning objects very highly in terms of learning, quality and engagement, quite a few students reported that using learning objects was an improvement over other teaching strategies.

Teacher vs. student ratings

Teacher and student impressions of learning objects and their effectiveness were relatively consistent. It appears however that teachers were more positive than students on all three survey constructs and especially when it came to rating engagement. This is an important finding because few studies compare teacher–student perceptions. Studies that glean feedback from only one of these populations may be underestimating or overestimating the impact of learning objects. Clearly it is important to gather data from both teacher and students to get a balanced perspective.

Student performance

Regardless of either teacher or student perceptions of the impact of learning objects, it is clear that learning performance increased markedly when learning objects were used. Although no previous research has looked at student performance in secondary schools, these results are consistent with those reported in higher education (Windschitl & Andre 1998; Rieber *et al.* 2004; Docherty *et al.* 2005). They also suggest that teacher analysis of learning in this study is more closely aligned to actual performance than student analysis. Students' modest ratings of learning did not the match significant jumps observed in performance.

The improvement in student performance does not mean that learning objects were uniquely responsible for these gains. A number of teachers used these tools in combination with a more formal lesson or class discussion, so the influence of learning objects is partially confounded by additional teaching techniques. It is reasonable, and perhaps ideal, that learning objects are integrated within a full classroom lesson that involves multiple teaching strategies.

Implications for education

There are several implications for secondary school educators who want to use learning objects in their classrooms. First, it will take about an hour to find and prepare a learning object lesson plan, but it may take as long as 2 h. Second, both teacher and students are positive about the use of learning objects in the classroom, although the impact of learning objects may vary considerably within the same classroom. Accommodations will have to be made for students with different ability and interest levels. Third, when learning objects are integrated into a lesson plan, student performance increases significantly. From the behaviour of most teachers in this study, combining the use of learning objects with a formal lesson using a brief introduction, supporting handout and/or class discussion may work well.

Caveats and future research

While considerable effort was made to ensure the reliability and validity of the results reported in this study, several limitations remain which offer opportunities for future research efforts. First, while the evidence suggests that learning objects had a positive impact in the classroom in terms of attitude and performance, without a control group it is difficult to determine the relative impact of the learning object technology itself. It is conceivable, for example, that other factors such as the structure afforded by the use of learning objects may be the critical component in the learning process, and not the technology. Second, even though the population was large and balanced in terms of gender, the subject speciality of most teachers was science and mathematics. Different results may be observed with other subject areas. Third, while the overall impact of learning object-based lessons on student performance was large, the effect of specific instructional strategies was not examined. In other words, we do not know which teaching strategies work best with learning objects. Finally, the study was designed to look at the overall impact of learning objects – the impact of specific kinds of learning objects was not looked at. It is possible that certain categories of learning objects may have decidedly different effects on learning.

Conclusions

This study adds significantly to the current knowledge regarding the use of learning objects. First, it looks at the secondary school population, a sector that has not been examined in much detail. Second, it looks at how teachers prepare for and use learning objects. Most secondary teachers take anywhere from one to 2 h to produce a lesson that is often focussed on review and to a lesser extent introducing a new concept. Previous learning object research is almost silent with respect to instructional strategies used with learning objects. Third, three forms of data collection were combined to analyse the impact of learning objects: teacher attitude, student attitude and student performance. This approach, rarely followed in learning object research, offered a reliable and valid method of evaluation. All three data sources confirmed that learning objects have a positive effect in secondary school classrooms. Finally, student performance increased by an average of almost 30% when learning objects were used in conjunction with other teaching strategies. This finding supports the premise that learning objects can be an effective teaching aid in secondary schools classrooms.

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Appendix A – Learning object evaluation scale – teachers.

	Strongly disagree 1	Disagree 2	Slightly disagree 3	Neutral 4	Slightly agree 5	Agree 6	Strongly agree 7
Learning							
1. The graphics and animations from the learning object helped students learn.	1	2	3	4	5	6	7
2. The students were able to learn from the learning object.	1	2	3	4	5	6	7
Quality							
3. The learning object was easy for students to use.	1	2	3	4	5	6	7
4. The learning object was easy to learn.	1	2	3	4	5	6	7

Appendix A *Continued*

	Strongly disagree 1	Disagree 2	Slightly disagree 3	Neutral 4	Slightly agree 5	Agree 6	Strongly agree 7
5. The students found the learning object instructions clear	1	2	3	4	5	6	7
Engagement							
6. The students liked interacting with the learning object.	1	2	3	4	5	6	7
7. The students were on task while using the learning object.	1	2	3	4	5	6	7
8. Students were motivated while using the learning object.	1	2	3	4	5	6	7
Overall Impact on Learning							
9. What was the overall impact of the learning object on your lesson?							

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
13. What, if anything, did you LIKE about the learning object?					
14. What, if anything, did you NOT LIKE about the learning object?					

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