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Analysing the Effectiveness of Learning Objects for Secondary School Science Classrooms

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The current study offers a comprehensive, systematic analysis of learning objects used in secondary school science classrooms. Five reliable and valid measures were used to examine the effectiveness of learning objects for 503 students and 15 teachers in 27 science classrooms. The results suggest that teachers typically spend 1-2 hours finding learning objects and preparing lessons that often focus on the review of previous material. 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 40%, when learning objects were used in conjunction with a variety of teaching strategies including brief introductions, letting students work on their own, and providing guiding handouts. It is reasonable to conclude that science-based learning objects are effective teaching tools in the secondary school environment.

A review of the literature on the use of technology in secondary school science classrooms (Kay & Knaack, 2007d) indicates that computers can be used to improve attitudes and learning performance; however, there is limited research on the use of web-based tools. A learning object defined as an "interactive web-based tool designed to enhance, amplify and guide learning," is a readily accessible, easy-to-learn, concept-focussed tool that is a promising alternative for teachers of science. In theory, good learning objects a require students to construct and manipulate information, provide rich feedback and interactive illustrations, help students understand abstract

ideas with concrete representations, and support important student weaknesses such as limited working memory, difficulty in retrieving long term memory, and ineffective learning strategies. The purpose of the following study was to systematically evaluate the effectiveness of learning objects in secondary school science classrooms.

LITERATURE REVIEW

Science and Technology in the Classroom

A review of 33 studies (Kay & Knaack, 2007d) on the effect of technology in secondary school science classrooms offers mixed results with respect to attitude and cognitive gains or learning performance. Out of 10 studies focussing on attitudes, three showed significantly positive increases, four revealed qualitative benefits, and three reported mixed or no differences when technology was used in the classroom. Out of 29 studies examining the cognitive impact of technology in science classrooms, seven noted significant quantitative gains, eight reported positive qualitative gains, twelve reported no change, and one identified a negative impact. Overall, it appears that technology in a secondary school science environment has had a relatively positive effect on attitudes and a positive or neutral effect on cognitions or learning performance.

The range of science-based technology intervention included specialized software, hardware, simulations, computer assisted instructions, general software, and the World Wide Web. No one technology stood out as being decidedly more effective, however, the strongest impact appeared to occur when new hardware was introduced, whereas mixed results occurred when specialized software was implemented. Limited research has been done examining the role of Internet resources in science education at the secondary school level (Kay & Knaack, 2007d).

It is important to note that the results reported from these 33 studies are partially compromised by limitations in methodology. Twenty-one studies (64%) offered no reliability estimates for measures used to assess change, and twenty-two (67%) presented no measure of validity.

Challenges to Using Technology

Educators face a number of challenges when attempting to use technology in their classrooms including the amount of time required (Eifler,

Greene, & Carroll, 2001; Wepner, Ziomek, & Tao, 2003), having to work with limited technological skills (Eifler et al., 2001; Strudler, Archambault, Bendixen, Anderson & Weiss, 2003; Thompson, Schmidt, & Davis, 2003), fear of technology (Bullock, 2004; Doering, Hughes, & Huffman., 2003), difficulty in understanding how to integrate technology into teaching (Cuban, 2001), and insufficient access (Bartlett, 2002; Brush et al., 2003; Russell, Bebell, O'Dwyer, & O'Connor, 2003). The positive results reported in 19 out of 33 studies reviewed by Kay & Knaack (2007d) indicate that there is potential for the use of technology in secondary school science classrooms to have positive impact. However, given the list of challenges, it is not surprising that technology has had a marginal impact in a number of instances.

Definition and Benefit of Learning Objects

Learning objects are defined in this study as "interactive web-based tools that support learning by enhancing, amplifying, and guiding the cognitive processes of learners." This definition was developed from an amalgamation of previous definitions (Agostinho, Bennett, Lockyer & Harper, 2004; Butson, 2003; McGreal, 2004; Parrish, 2004; Wiley, et al., 2004).

Researchers have argued that learning objects offer considerable potential as effective learning tools (Akpinar & Bal, 2006; Liu & Bera, 2005; Nurmi & Jaakkola, 2006; Reimer & Moyer, 2005); however careful consideration is required in the selection process. It is hypothesized that good learning objects should (a) require students to construct and manipulate (Akpinar & Bal, 2006; Baser, 2005; Nurmi & Jaakkola, 2006), (b) provide rich feedback and interactive illustrations (Akpinar & Bal, 2006), (c) help students understand abstract ideas with concrete representations (Akpinar & Bal, 2006; Reimer & Moyer, 2005) and (d) support key student weaknesses like limited working memory, difficulty in retrieving long term memory, and ineffective cognitive strategies (Liu & Bera, 2005).

In addition, it is emphasized that instructional strategies supporting the use of learning objects are critical for success, regardless of the quality of the learning object selected (Akpinar & Bal, 2006; Clarke & Bowe, 2006a; Nurmi & Jaakkola, 2006; Reimer & Moyer, 2005). A judicious mix of instruction, exploration, practice and reflections is ideal (Nurmi & Jaakkola, 2006). To date, the above list of hypotheses and speculations about the effective use of learning objects remains largely untested, particularly in the secondary school classroom.

Impact of Learning Objects in Science

A comprehensive review of learning objects in the past 10 years uncovered 11 articles focussing on the use of learning objects in science (Akpinar & Bal, 2006; Baser, 2005; Clarke & Bowe, 2006a, 2006b; Howard-Rose & Harrigan, 2003; Kay & Knaack, 2007d; Liu & Bera, 2005; Nurmi & Jaakkola, 2006; Rieber ,Tzeng, & Tribble, 2004; Schoner et al., 2005; Windschitl & Andre, 1998). Note that, aside from Windschitl & Andre (1998), these studies go back no further than 2005, indicating that research in this domain is in its infancy.

Context. The context of use varied considerably with respect to grade level, time spent using learning objects, number of objects evaluated, and implementation strategies. In terms of grade level, two studies looked at elementary school students (Clarke & Bowe, 2006a, 2006b), three studies looked at middle school students (Akpinar & Bal, 2006; Liu & Bera, 2005; Nurmi & Jaakkola, 2006), one study examined high school students (Kay & Knaack, 2007d), and five studies focussed on higher education students (Baser, 2005; Howard-Rose & Harrigan, 2003; Rieber et al., 2004; Schoner et al., 2005; Windschitl & Andre, 1998). With respect to time spent using learning objects, some students used learning objects for 40-60 minutes (Akinpar & Bal, 2006; Kay & Knaack, 2007d; Nurmi & Jaakkola, 2006), while other students used learning objects over several weeks (Clarke & Bowe, 2006a; Clarke & Bowe, 2006b; Liu & Bera, 2005). Regarding the number of learning objects evaluated, most papers focussed on a single learning object, however several researchers looked at multiple learning objects (Clarke & Bowe, 2006a; 2006b; Kay & Knaack, 2007d; Nurmi & Jaakkola, 2006). Finally, with implementation strategies, some teachers played a facilitating role, allowing students to explore learning objects on their own (Liu & Bera, 2005; Kay & Knnack, 2007d; Nurmi & Jaakola, 2006), while other teachers reported the use of multiple strategies such as large group discussion, guided worksheets, collaborative learning, and writing reflective comments (Clarke & Bowe, 2006a; 2006b; Rieber et al., 2004; Windschitl & Andre, 1998).

Teacher perspective. Only three studies looked specifically at teachers attitudes toward the use of learning objects in the science classroom (Akinpar & Bal, 2006; Clarke & Bowe, 2006a; Clarke & Bowe, 2006b). Based on qualitative data collection methods, teachers valued three main characteristics of learning objects: the immediate feedback provided the ability to replay and redo tasks for both enjoyment and mastery, and the motivational impact. Akinpar & Bal (2006) noted that teachers also enjoyed collaborating with their peers with respect to reviewing and modifying learning object based lessons.

Student perspective. Six studies examined student attitudes toward learning objects. Science students reported liking learning objects because they were (a) fun and enjoyable, (b) easy to control with respect to the pace of learning, (c) easy to use, (d) provided timely feedback, (e) consisted of a number multimedia tools, and (f) helped them learn (Clarke & Bowe, 2006a; Clarke & Bowe, 2006b; Howard-Rose & Harrigan, 2003; Kay & Knaack, 2007d; Nurmi & Jaakkola, 2006; Reimer & Moyer, 2005). Overall, students reported being "moderately" positive about the use of science-based learning objects (Howard-Rose & Harrigan, 2003; Kay & Knaack, 2007d).

Student performance. While seven studies looked at student performance while using science-based learning objects, none were done at the secondary school level (Akpinar & Bal, 2006; Baser, 2005; Liu & Bera, 2005; Nurmi & Jaakkola, 2006; Rieber et al., 2004; Schoner et al., 2005; Windschitl & Andre, 1998). In all seven studies, students who used learning objects showed significant improvement on various performance measures. Several contextual details, though, are worth noting.

Nurmi & Jaakkola (2006) noted that learning performance was dependent on the type of learning object and how it was used. Students working with drill and practice learning objects tended to be less focussed on learning and more focussed on competing with their peers. Students involved in a mixed learning object / lab-based lesson, performed significantly better than in other learning scenarios. Rieber et al. (2004) reported that students with graphical feedback did significantly better than there peers with textual feedback. Finally, Windschitl & Andre (1998) observed performance varied depending on the learning object environment (constructivist learning vs. set-by-step).

Methodological Issues

This study reviewed 11 articles looking at the use of learning objects science classrooms, although only one paper focussed on secondary schools. It is commendable that most of these studies emphasized student performance, a pattern that has not been observed at higher levels of education (Kay & Knaack, 2005; 2007c). That said a number of issues need to be addressed to improve the investigation of learning objects.

First, while there are good descriptions of how teacher use learning objects, limited information is provided on teacher attitudes toward learning objects. Only three studies examined teacher perspectives' on learning objects (Clarke & Bowe, 2006a; Clarke & Bowe, 2006b; Kay & Knaack, 2007d).

Second, even though a wide range of learning objects exist, the majority of papers focus on a single learning object. It is difficult to determine whether the evaluation tools used in one study generalize to the full range of learning objects that are available.

Third, sample populations tested in K-12 studies are relatively small and weakly described making it challenging to extend any conclusions to a larger population. All but one study (Kay & Knaack, 2007d) examined less than 70 students.

Fourth, triangulation of data collection is somewhat limited with only two studies using more than two data collections procedures (Howard-Rose & Harrigan, 2003; Schoner et al., 2005). In addition, no researchers looked at student attitude, teacher attitude, and student performance simultaneously.

Finally, while most evaluation studies reported that students benefited from using learning objects, the evidence is based on assessment tools with no validity or reliability. Only four studies reviewed offered reliability estimates (Baser, 2005; Kay & Knaack, 2007d; Liu & Bera, 2005; Windschitl & Andre, 1998) and one study, validity confirmation (Kay & Knaack, 2007d). The lack of reliability and validity of evaluation tools reduces confidence in the results presented to date.

In summary, previous methods used to evaluate learning objects are limited with respect to examining multiple perspectives of learning objects, particularly those of teachers, number of learning objects assessed, sample size, reliability, and validity.

Purpose

The purpose of this study was to examine the impact of learning objects in secondary school science classrooms from the perspective of both teachers and students.

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. both qualitative and quantitative data were collected;
4. both teacher and student perspectives were assessed;

5. a measure of student performance was included; and
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 27 classrooms (a number of teacher used learning objects more than once). Teaching experience ranged from 2 to 33 years with a mean of 9.4 (*SD* = 7.7). Subjects taught included general science (n=6), biology (n=3), chemistry (n=3), and physics (n=3). 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=12). In spite of the high computers ability and positive attitudes, only four of the teachers used computers in their classrooms more than once a month.

Students. The student sample consisted of 503 secondary school students (258 males, 245 females), 14 to 22 years of age (*M* = 16.6, *SD* = 1.1). The population base spanned three separate boards of education and 11 secondary schools. 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 21 unique learning objects were selected covering concepts in biology, chemistry, general science, and physics (see Table 1).

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 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, 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 complete a pre and post test based on the content of the learning object.

Table 1

List of Science Based Learning Objects Used in the Study

Collection	Name	Web Address	Status
Amazing Space	Space Trading Cards	http://amazing-space.stsci.edu/resources/explorations/trading/directions.html	Open
BBC	Rocks and Soil	http://www.bbc.co.uk/schools/scienceclips/ages/7_8/rocks_soils.shtml	Open
Creative Chemistry	Balancing Equations	http://www.creative-chemistry.org.uk/gcse/revision/equations/index.htm	Open
Discovery	Weather Extreme: Tornado	http://dsc.discovery.com/convergence/tornado/tornado.html	Open
Dolan DNA	Gel electrophoresis	http://www.dnai.org/b/index.html	Open
FunBased Learning	Classic Chembalancer	http://funbasedlearning.com/chemistry/chemBalancer/	Open
Greenbowe	Metals in Aqueous Solutions	http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/animationsindex.htm	Open
LEARN	Ohm Zone	http://www.article19.com/shockwave/oz.htm	Open
Learn Alberta	Ammeters and Voltmeters	http://www.learnalberta.ca/Main.aspx	Protected
Learn Alberta	Multiplying and Dividing Cells	http://www.learnalberta.ca/Main.aspx	Protected
PBS	Structure of Metals	http://www.pbs.org/wgbh/nova/wtc/metal.html	Open
Region of Waterloo	Waterloo: Hydrologic Cycle	http://www.region.waterloo.on.ca	Open
The Biology Project	Online Onion Root Tips	http://www.biology.arizona.edu/Cell_bio/activities/cell_cycle/cell_cycle.html	Open
The Learning Federation	Alpha, Beta, Gamma of Rad	http://www.thelearningfederation.edu.au/tlf2/	Protected
The Learning Federation	Reading Between the Lines	http://www.thelearningfederation.edu.au/tlf2/	Protected
U of Colorado (PhET)	Energy Skate Park	http://phet.colorado.edu/new/simulations/index.php	Open
UOIT	Capillary Fluid Exchange	http://education.uoit.ca/EN/main/151820/151827/research_teach_locollection.php	Open
UOIT	Charging an Electroscope	http://education.uoit.ca/EN/main/151820/151827/research_teach_locollection.php	Open
UOIT	Relative Velocity - UOIT	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
Wisconsin Online	Periodic Table	http://www.wisc-online.com/objects/index_tj.asp?objid=SCI202	Open

Data Sources

Teacher Use. Teachers were asked (a) how long it took them to find and integrate learning objects into their classroom, (b) their purpose for using the learning object (e.g., motivate students, teach a new concept, review, supplementing a lesson) and (c) 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 (a) how much their students learned (learning construct), the quality of the learning object (quality construct), how much there students were engaged with the learning object (engagement construct). The constructs selected were based on a thorough review of the literature (Kay & Knaack, 2007a, 2007b, 2007e). The LOES-T showed fair to moderate reliability and good construct validity (see Kay & Knaack, 2007e).

Teacher comments. Finally, teachers were asked to comment on the overall impact that the learning object had on learning (Q9, 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 (a) how much they learned (learning construct), the quality of the learning object (quality construct), 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, 2007a, 2007b, 2007e). The scale showed good reliability (0.78 to 0.89), face validity, construct validity, convergent validity, and predictive validity (see Kay & Knaack, 2007e).

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 analysed according to the coding scheme provided in Table 2. This coding scheme (Kay & Knaack, 2007) was used to categorize 797 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 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 6, the impact of visual supports on learning was calculated by multiplying the mean which was 0.90 by the number of student who commented about visual supports (62) for a total of 56.0.

Table 2

Coding Scheme to Categorize Student Comments about Learning Objects

Learning

Category Label	Criteria
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

Engagement

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"
Compare	Student compares LO to another method of learning
Engage	Student refers to program as being OR not being fun/enjoyable/engaging/interesting
Interactive	Student refers to some interactive part feature of the LO
Technology	The student mention a technological issue with respect to using the LO

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
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

Student performance. Students completed a pre-test and pos-test based created by each teacher based on the content of the learning object used in class. The measure was used to determine student performance.

Key Questions & Data Analysis

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

1. How do teachers use learning objects in their classrooms? (descriptive analysis of teacher use questions);
2. How do teachers rate learning, quality, and engagement of learning objects? (descriptive analysis of teacher survey – LOES-T);
3. What was the overall impact of learning objects according to teachers? (analysis of qualitative teacher comments);
4. How do students rate learning, quality, and engagement of learning objects? (descriptive analysis of student survey – LOES-S);
5. What do student like and dislike most about learning objects? (qualitative analysis of student comments);
6. How do teacher ratings of learning objects compare with student ratings? (correlation among learning, quality, and engagement constructs) and
7. How do learning objects affect student performance (t-test comparing pre and post scores)?

RESULTS

Use of Learning Objects

Finding a learning object. Thirty-seven percent (n=10) of the teachers reported that finding the right learning object took them less than 30 minutes. Forty-four percent (n=12) took 30 to 60 minutes to find an appropriate learning object. The remaining 19% (n=5) took over an hour to find 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, 7 % (n=2) of the teachers spent little or no time, 48% (n=13) spent less than 30 minutes, 33% (n=9) spent 30 to 60 minutes, and the remaining 11% (n=3) spent over an hour.

Using a learning object. On average, teachers used learning objects for 33.8 minutes (*SD* 19.1), however there was considerable variability (6 to 75 minutes). Students worked on there own on computers in a majority of classrooms (93%, n=25), with cooperative learning chosen only 7% of the time.

Reason for using a learning object. The top two reasons given by teachers for using learning objects was to review a previous concept (59%, n=16) and to motivate students about a topic (41%, n=11). Teachers also used learning objects to provide another way to look at a concept (30%, n=8) or explore a new concept before a formal lesson (25%, n=7). Teachers rarely

used learning objects to teach a new concept (7%, n=2), for homework (7%, n=2), or to explore a new concept after a formal lesson (4%, n=1).

Strategies for using learning objects. Teachers in this study typically provided a brief introduction to a learning object (59%, n=16) and/or let the students start exploring on their own (44%, n=12). Only 11% (n=3) offered a formal demonstration of the learning object before the class used it. Thirty-seven percent of teachers (n=10) prepared a formal handout with questions to be use by students while using the learning object. Thirty-three percent of teachers (n=9) 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 11.8 (*SD* = 1.5) or 5.9 on a 7-point scale. This suggests that most teachers agreed that the learning object 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 believed learning objects offered learning benefits (see Table 3).

Quality of Learning Object. The mean rating of learning object quality was 18.3 (*SD* = 2.0) or 6.1 on a 7-point scale. Most teachers agreed or strongly agreed the learning object was of good quality. The range of learning object quality scores was broader than that observed for the learning construct (11 to 21), but never dipped into negative rating (Table 3).

Engagement. Teachers also rated engagement of learning objects quite high with a mean score of 17.5 (*SD* = 3.0) or 5.8 on a 7-point scale. A majority of teachers, then, believed 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).

Table 3
Teacher Rating of Learning, Quality, and Engagement for Learning Objects

Scale	No. Items	Possible Range	Actual Range Observed	Mean (S.D)
Learn	2	2 to 14	8 to 14	11.8 (1.5)
Quality	3	3 to 21	11 to 21	18.3 (2.0)
Engagement	3	2 to 21	9 to 21	17.5 (3.0)

Teacher comments about learning objects. Three themes emerged from the 40 comments that teachers made about the overall impact of the learning object: learning (n=29, 73%), engagement (n=6, 15%), and time (n=5, 13%). Details for each theme and sample comments offered by teachers are presented in Table 4.

Table 4
Qualitative Comments from Teachers

Category	n	%	Sample Comments
Learning			
Review	11	28%	"I think this learning object was helpful in reinforcing information previously taught." "Reinforced concepts and provided a method to review that wasn't perceived as boring to the students." "Overall, as the students went through the questions, they pieced together what they had been previously taught."
Visual Supports	8	20%	"The learning object provided an animated visual to a difficult topic of charging an electroscope." "The kids were exposed to an animated, interactive version of something they would most likely normally get out of the textbook."
Overall Success	8	20%	"I feel that the students gained a good insight into a new concept - it will help throughout this unit." "Students had a much better background in the subject when it was introduced [using learning objects]"
Engagement	6	15%	"It helped to motivate them during the formal teaching after the learning object." "It was good. Students were more motivated."
Time	5	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."

With respect to learning, 28% (n=11) of the teachers commented that learning objects served as good review tools. Other teachers noted that learning objects offered good visual supports (n=8, 20%) for supplementing learning. Finally, 20% (n=8) of the teachers noted that learning, in general, improved with learning objects.

Fifteen percent of the teachers (n=6) noted that one of the key impacts of the learning object was engagement. Students were more interested or motivated when using this tool. Some teachers (n=5) 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.

Student Rating of Learning Objects

Learning. Students rated learning objects lower than teachers with respect to learning (M=17.8, SD = 4.0) with a mean item rating of 3.6 out 5 (or 5.0 out of 7). Students tended to agree that learning objects contributed to their learning. The range of scores was extensive (5 to 25) indicating that there was considerable variability with respect to whether students thought learning objects helped them learn (Table 5).

Quality of Learning Objects. Students typically agreed that the quality of learning objects was good with a mean item rating was 4.0 out of 5 (5.5 or out 7). The range of learning object quality scores (4 to 20) demonstrated considerable variability (Table 5).

Engagement. Ratings of learning object engagement were moderate (M=10.7, SD = 2.4) with a mean item rating of 3.6 out or 5 (or 4.8 out of 7). In other words, as was the case with the learning construct, students tended to agree that the learning object were engaging. High variability among student engagement ratings is supported by the wide range of scores reported (3 to 15).

Table 5

Description of Student Learning Object Evaluation Scales (LOES-S)

Scale	No. Items	Possible Range	Actual Range Observed	Mean (S.D)
Learn	5	5 to 25	5 to 25	17.8 (4.0)
Quality	4	4 to 20	4 to 20	15.8 (2.8)
Engagement	3	3 to 15	3 to 15	10.7 (2.4)

Student comments about learning objects. Student comments are summarized in Table 6. With respect to learning, the visual supports were rated the highest, whereas the pedagogical challenge of learning objects was rated quite low. In other words, many students liked the visual aspects of learning objects; however, quite a few believed 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 graphics and animation. On the other hand, lack of control over a learning object, the quality of help, and the excessive amount of text were rated the lowest.

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

Table 6

Summary of Student Comments about Learning Objects

Category	Mean	S.D	n	Total Effect Mean * n
Learning				
Visual Supports	0.90	0.44	62	56.0
Overall Learning	0.15	1.09	105	16.0
Challenge	-0.48	1.06	95	-46.0
Quality				
Easy	0.96	0.46	48	46.0
Graphics	0.38	0.97	66	25.0
Animation	0.63	0.79	38	24.0
Theme	-0.04	1.24	25	-1.0
Organization	-0.09	1.10	33	-3.0
Audio	-1.00	0.00	5	-5.0
Help	-0.33	1.11	68	-13.0
Text	-0.81	0.75	16	-13.0
Control	-0.65	0.89	26	-17.0
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

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 sample of 138 students. Student performance scores increased by an average of 38.9% from 37.8% to 76.6%. This change was significant (t = -17.4, df = 137, p < .001). The effect size (based on Cohen's d) of 1.10 is considered very large according to Thalheimer & Cook (2002).

DISCUSSION

The purpose of this study was to examine the effects of learning objects in secondary school science classrooms. Evidence used to evaluate effectiveness was collected from teachers (use, ratings, qualitative comments) and students (ratings, qualitative comments about what they liked and did not like, performance). The results from each of these six measures will be discussed in turn.

Teacher Use

Previous research says little about how teachers find learning objects and prepare to use them in the science classroom. This study provides some new data in this area. Searching for and planning to use a learning object does not take excessive time – roughly an hour on average. Teachers made minimal reference to preparation time in their comments, so we can cautiously conclude that this aspect learning object use is not a prohibitive influence.

It is interesting that about 60% of science teachers used learning objects to supplement the curriculum focussing on concepts that had already been covered. Only one quarter used learning objects to help introduce a new topic before a formal lesson or to teach a new concept on its own. One interpretation of this behaviour is that teachers are being cautious with a new teaching tool in their classroom. It would be interesting to investigate long term use of learning objects to see if science teachers would shift strategies once they became more confident that the tools work.

With respect to using learning objects, most teachers offered a brief introduction with 40% letting students explore on their own. This finding is consistent with the behaviour of science teachers observed in previous re-

search (Liu & Bera, 2005; Nurmi & Jaakola, 2006). Only one third of the teachers prepared a formal handout, leaving students 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 also might reflect an underlying belief that a learning object should stand by itself as a teaching tool.

Teacher Ratings (Learning, Quality, and Engagement)

It is clear teachers believed that the learning objects they selected were good quality, engaging tools that supported learning. Ratings were very high, often 6 on a 7-point Likert scale. On the one hand, we would expect teachers to rate learning objects high, since they selected them in the first place. On the other hand, teachers rated these learning objects after they watched them being used by students in their classroom. In addition, they had no personal stake in approving these tools. Positive reaction from teachers in this study is consistent with previous findings for science teachers using learning objects (Akinpar & Bal, 2006; Clarke & Bowe, 2006a; Clarke & Bowe, 2006b).

Teacher Comments

With respect to learning, teacher comments supported both survey and learning performance results. Teachers felt that the learning objects offered a good review of concepts, helpful visual supports, and good learning support. In addition, learning objects were thought to be engaging. These comments are consistent with observations made by previous researchers (Akinpar & Bal, 2006; Clarke & Bowe, 2006a; Clarke & Bowe, 2006b).

Student Ratings (Learning, Quality, and Engagement)

On average, students took a moderate stance on the learning, quality, and engagement impact of learning objects. These results are consistent with the modest enthusiasm expressed in the one study evaluating the use of science-based learning objects in secondary school (Kay & Knaack, 2007d). It is worth noting, though, that the range of scores was broad for all three constructs. For any given learning object, some students may like it a lot

and other may dislike it. Learning objects, in spite of the many proposed benefits, may not suit every student's learning needs. The challenge that remains is to identify the sources of individual differences.

Finally, teachers rated learning, quality, and engagement higher than students. What science teachers think is an effective, high quality, motivating teaching tool, may be perceived as moderately acceptable by students. This discrepancy does not appear to have an impact on actual learning, given the significant improvement in student performance observed.

Student Comments about Learning Objects

Student comments offer insight into what students like and do not like about learning objects. Ease of use, interactivity, and visual supports were favoured, whereas lack of control, quality of help, and the excessive amount of text appeared to be the most bothersome.

These comments are similar to those made by students in previous studies (Clarke & Bowe, 2006a; Clarke & Bowe, 2006b; Howard-Rose & Harrigan, 2003; Kay and Knaack, 2007d). Finally, even if student response to learning objects is perceived as lukewarm, a number of students reported that using learning objects was an improvement over other teaching methods.

Student Performance

This is a first study on the impact of learning objects in secondary school science with respect to learning performance. The fact that learning performance increased is not surprising given the wealth of previous research that has reported similar results at other grade levels (Akpinar & Bal, 2006; Baser, 2005; Liu & Bera, 2005; Nurmi & Jaakkola, 2006; Rieber, Tzeng, & Tribble, 2004; Schoner, Buzza, Harrigan, & Strampel, 2005; Windschitl & Andre, 1998). However, the magnitude of effect (almost 40%) is very large – effect size has not been reported in past studies. The data also suggest that teacher assessment of learning impact in this study is more closely aligned to performance that than student assessment of learning.

The improvement in student performance does not mean that learning objects were independently responsible. As in previous studies (Clarke & Bowe, 2006a, 2006b; Rieber et al., 2004; Windschtil & Andre, 1998), a number of teachers used these tools in combination with a more formal les-

son or class discussion, so the influence of learning objects is partially confounded by additional teaching techniques. It is reasonable, and even desirable, 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 science educators who intend to use learning objects in their classrooms. First, it will take, on average about an hour to find and prepare to use learning objects; however it may take as long as two hours. Second, even though both teachers and students are positive about the use of learning objects in the classroom, the impact of learning objects may vary greatly within the same classroom. Accommodations could have to be made for students with different ability and interest levels. Third, it appears that using learning objects to help teach new concepts leads to significant improvements in learning performance. From the behaviour of teachers in this study, combining the use of learning objects with a formal lesson using a brief introduction and /or a prepared handout may work well.

Caveats and Future Research

A concentrated effort was made to collect high quality data in this study by sampling a large, relatively diverse population, establishing the reliability and validity of measures used, and using multiple data sources to establish triangulation. Nonetheless, several limitations exist which provide opportunities for future researchers. First, while the overall impact of learning-object lessons on student performance was large, the impact of specific instructional strategies was not examined. In other words, we don't know which teaching strategies work best with learning objects. Perhaps different strategies work with different kinds of learning objects.

Furthermore, 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 impacts on learning. For example, a tool-based learning object may be good for exploring a new concept where as a question-and-answer learning object may be best for review. Developing and evaluating a classification system for learning objects may be an important next step in learning object research.

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Appendix A – Learning Object Evaluation Scale for 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
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?