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A Systematic Evaluation of Learning Objects for Secondary School Students

Abstract

Empirical research evaluating the effectiveness of learning objects is noticeably absent. No formal research has been done on the use of learning objects in secondary schools. The purpose of this study was to evaluate the use of learning objects by high school students. The evaluation metric used to assess benefits and quality of learning objects was theoretically sound, reliable, and valid. Overall, two thirds of the students stated they benefited from using learning objects. Students benefited more if they were comfortable with computers, the learning object had a well organized layout, the instructions were clear, and the theme was fun or motivating. Students appreciated the motivational, interactive, visual qualities of the learning objects most. Computer comfort was significantly correlated with learning object quality and benefit. Younger students appeared to have less positive experiences than their older counterparts. There were no gender differences in perceived benefit or quality of learning objects, with one exception. Females emphasized the quality of help features significantly more than males.

Keywords: develop, evaluate, secondary school, learning object

A Systematic Evaluation of Learning Objects for Secondary School Students

Overview

In the past 10 years, considerable money and effort has been directed toward introducing technology into education. However, the success of this extensive undertaking has been mixed at best. Multiple obstacles experienced by elementary and secondary school teachers have impeded technological progress in the classroom and include lack of time, insufficient access to software and hardware, limited technological skill, low confidence, and not understanding how to integrate technology into teaching. If real world obstacles experienced by teachers continue to be ignored, it is highly unlikely that technology will play a significant role in classroom learning.

Learning objects are potentially promising tools that (a) address many of the barriers that teachers experience with technology and (b) are based on sound learning theory examined over the past 15 years. In spite of a long list of potential benefits, little research has been done examining the actual use and impact of learning objects in the classroom, particularly in secondary schools. Many prominent learning object theorists argue that research on the effectiveness of learning objects in the classroom is long overdue.

The purpose of this study was to systematically evaluate the use of learning objects by secondary school students. Emphasis was placed on (a) a pedagogically guided model of learning objects, (b) a comprehensive evaluation metric examining the quality and benefits of learning objects, and (c) exploring individual differences in use (computer comfort, gender, and grade level).

Literature Review

Technology and Education

Over the past 10 years, a substantial effort has been made to increase the use of technology in the classroom (Compton & Harwood, 2003; McRobbie, Ginns, & Stein, 2000; Plante & Beattie, 2004; US Department of Education, National Center for Education Statistics, 2002). In spite of these efforts, a number of researchers have argued that technology has had a minor or negative impact on student learning (e.g., Cuban, 2001; Roberston, 2003; Russell, Bebell, O'Dwyer, & O'Connor, 2003; Waxman, Connell, & Gray, 2002). Part of the problem stems from a considerable list of obstacles that have prevented successful implementation of technology including a lack of time (Eifler, Greene, & Carroll, 2001; Wepner, Ziomek, & Tao, 2003), limited technological skill (Eifler et al., 2001; Strudler, Archambault, Bendixen, Anderson & Weiss, 2003; Thompson, Schmidt, & Davis, 2003), fear of technology (Bullock, 2004; Doering, Hughes, & Huffman, 2003), a clear lack of understanding about how to integrate technology into teaching (Cuban, 2001), and insufficient access (e.g., Bartlett, 2002; Brush et al., 2003; Russell et al., 2003).

The Role of Learning Objects

Learning objects, defined in this proposal as "interactive web-based tools that support learning by enhancing, amplifying, and guiding the cognitive processes of learners" (Agostinho, Bennett, Lockyer & Harper, 2004; Butson, 2003; Friesen, 2001; Gibbons, Nelson & Richards, 2002; Littlejohn, 2003; Metros, 2005; McGreal , 2004; Muzio, Heins & Mundell, 2002; Parrish, 2004; Polsani, 2003; Wiley, 2000; Wiley, et al. 2004), offer a number of key components that can reduce the impact of potential obstacles observed in the past (accessibility, ease of use, reusability) and enhance student learning (interactivity, graphics, reduction of cognitive load, adaptive).

In contrast to other learning technologies burdened with implementation challenges and costs, learning objects are readily *accessible* over the Internet and users need not worry about excessive costs or not having the latest version (Wiley, 2000). Well over 90% of all public schools in North America and Europe now have access to the Internet (and therefore learning objects) with most having high-speed broadband connections (Compton & Harwood, 2003; McRobbie, Ginns, & Stein, 2000; Plante & Beattie, 2004; US Department of Education, National Center for Education Statistics, 2002). In addition, because of their limited size and focus, learning objects are relatively *easy to learn and use*, making them much more attractive to busy educators who have little time to learn more complex, advanced software packages (Gadanidis, Gadanidis, & Schindler, 2003). Finally, *reusability* permits learning objects to be useful for a large audience, particularly when the objects are placed in well organized, searchable databases (e.g., Agostinho et al., 2004; Duval, Hodgins, Rehak & Robson, 2004; Rehak & Mason, 2003).

With respect to enhancing learning, many learning objects are *interactive* tools that support exploration, investigation, constructing solutions, and manipulating parameters instead of memorizing and retaining a series of facts. The success of this constructivist based model is well documented (e.g., Albanese & Mitchell, 1993; Bruner, 1983, 1986;

Carroll, 1990; Caroll & Mack, 1984; Collins, Brown, & Newman, 1989; Vygotsky, 1978). In addition, a number of learning objects have a *graphical component* that helps make abstract concepts more concrete (Gadanidis et al., 2003). Furthermore, certain learning objects allow students to explore higher level concepts by *reducing cognitive load*. They act as perceptual and cognitive supports, permitting students to examine more complex and interesting relationships (Sedig & Liang, submitted for publication). Finally, learning objects are *adaptive*, allowing users to have a certain degree of control over their learning environments, particularly when they are learning and for how long.

In spite of this long list of potential benefits, little research has been done examining the actual use and impact of learning objects in the classroom (Bradley & Boyle, 2004; Kenny, Andrews, Vignola, Schilz, & Covert, 1999; Van Zele, Vandaele, Botteldooren & Lenaerts, 2003). The few studies examining the use of learning objects have concentrated exclusively on higher education. No formal, published studies were found investigating the use of learning objects for secondary school students.

Learning Object Research

An extensive review of the literature uncovered 58 articles related to learning objects. Fifty of these papers were theoretical in nature – they did not offer formal evaluations to support claims made. Acknowledging that a single paper could cover more than one topic, the following topics were addressed: design (n=24; 41%), metadata (n=17; 29%), learning (n=17; 29%), reusability (n=12; 29%); development (n=11; 19%); evaluation (n=11; 19%), definition (n=9; 16%); repositories and searching (n=9; 16%); use (n=7; 12%), and standards (n=5; 9%) . The majority of these issues covered are technology-focused with relatively little discussion on learning, evaluation, and use.

A number of authors note that the “learning object” revolution will never take place unless instructional use and pedagogy is explored and evaluated (Maclaren, 2004; Muzio et al., 2002; Richards, 2002; Wiley, 2000). Agostinho et al. (2004) and Wiley (2000) add that the learning object research agenda must begin to investigate how learning objects can be used to create a high quality instruction or "we will find ourselves with digital libraries full of easy to find learning objects we don't know how to use" (p.2, Agostinho et al., 2004). Finally, Duval et al., (2004) note that while many groups seem to be grappling with issues that are related to the pedagogy and learning objects, few papers include a detailed analysis of specific learning object features that affect learning. Clearly, there is a need for empirical research that focuses on the pedagogical qualities of learning objects.

Evaluation of Learning Objects

Only eight out of the 56 papers reviewed in this study evaluated the actual use of learning objects (Adams, Lubega, Walmsley, & Williams, 2004; Bradley & Boyle, 2004; Cochrane, 2005; Kenny, et al., 1999; Krauss & Ally, 2005; Macdonald et al., 2005; Nesbit, Belfer, & Vargo, 2002; Van Zele, et al., 2003). Various methods of evaluation were used including informal or qualitative feedback (Adams et al., 2004; Bradley & Boyle, 2004; Cochrane, 2005; Macdonald et al., 2005), descriptive analysis (Krauss & Ally, 2005; Macdonald et al., 2005), convergent participation (Nesbit et al., 2002), formal surveys (Cochrane, 2005; Krauss & Ally, 2005), and learning outcomes (Adams et al., 2005; Bradley & Boyle, 2004; Macdonald et al., 2005; Van Zele et al., 2003).

In all eight studies, students and/or professors reported that learning objects had a positive impact. Learning objects that offered clear instructions, engaging activities, and interactivity (Cochrane, 2005; Krauss & Ally, 2005; Macdonald et al., 2005) were rated as most successful. The results from these studies, though, are limited in several ways. First, the research has been done exclusively with university students. Second, while all eight studies reported that students benefited from the learning objects, the evidence was gathered, for the most part, from loosely designed assessment tools with no validity or reliability. Third, a formal statistical analysis was done in only two studies (Adams et al., 2004; Van Zele et al., 2003). Finally, only three studies explored the impact of specific learning object characteristics (Kenny et al., 1999; Cochrane, 2005; Krauss & Ally, 2005). More formal, systematic research on broader populations is needed with respect to evaluating the impact of learning objects (Duval et al., 2004).

Computer Attitudes

Considerable research has been done on the effect of attitude on computer related behaviour (Barbeitte & Weiss, 2004; Christensen & Knezek, 2000; Durndell & Haag, 2002; Kay, 1989, 1993b; Liu, 2004; Torkzadeh, Pflughoeft, & Hall, 1999). In general, more positive computer attitudes are associated with higher levels of computer ability and use. Self-efficacy or perceived comfort with using computers has been to shown to be particularly influential on computer related behaviours (e.g., Barbeite & Weiss, 2004; Durndell & Haag, 2002; Shapka & Ferrari, 2003; Solvberg, 2002). Self-efficacy has not been examined with respect to the use of learning objects, although it is expected that students who are more comfortable with computers will benefit more.

Gender Differences in Computer Behaviour

In 1992, Kay reviewed 36 studies on gender and computer related behaviours. While there were clear measurement concerns regarding the assessment of gender differences in computer ability, attitude and use (e.g., Kay, 1992, 1993a), the overall picture indicated that males had more positive attitudes, higher ability, and used computers more. Five years later, a meta-analysis by Whitley (1997) revealed the imbalance between males and females continued to exist with respect to computer attitudes. Males had greater sex-role stereotyping of computers, higher computer self-efficacy, and more positive affect about computers than females. In a recent review (Kay, in press), differences between males and females appear be lessoning somewhat, although male dominance is still prevalent with respect to attitude, ability, and use. Only one study has looked at gender differences with respect to computer attitudes and learning objects – no significant differences were found between male and female university students (Van Zele, et al., 2003).

Purpose

The purpose of this study was to systematically evaluate the use of learning objects by secondary school students. The key questions addressed were:

1. What were the reported benefits of using the learning objects (perceived benefit)?

2. What did students like and dislike about using learning objects (quality of learning objects)?
3. What was the impact of computer comfort level, gender, grade, and learning object type on the perceived benefits and assessment of learning quality?

Method

Sample

Students. The sample consisted of a 221 secondary school students (104 males, 116 females, 1 missing data), 13 to 17 years of age, in grades 9 (n=85), 11 (n=67), and 12 (n=69) from twelve different high schools and three boards of education. The students were obtained through convenience sampling.

Teachers. A total of 30 teachers (9 experienced, 21 preservice) participated in the development of the learning objects. Experienced teachers had taught for 10 or more years. Pre-service teachers had completed at least a B.A. or B.Sc. and were enrolled in an 8-month bachelor of education program. The breakdown by subject area was eight for

Biology (two experienced, six preservice), five for Chemistry (two experienced, three preservice), five for Computer Science (one experienced, four preservice), five for Physics (one experienced, four preservice), and seven for Math (three experienced, four preservice).

Learning Objects. Five learning objects in five different subject areas were evaluated by secondary school students. Seventy-eight students used the Mathematics learning object (grade 9), 40 used the Physics learning object (grades 11 and 12), 37 used the Chemistry learning object (grade 12), 34 used the Biology learning object (grades 9 and 11), and 32 used the Computer Science learning object (grades 11 and 12).

All learning objects can be accessed at: http://education.uoit.ca/learningobjects . A brief description is provided below.

The mathematics learning object (Deep Space Line) was designed to help grade 9 students explore the formula and calculations for the slope of a line. Students used their knowledge of slope to navigate a spacecraft through four missions. As the missions progressed from level one to level four, less scaffolding was provided to solve the mathematical challenges.

The physics learning object (Relative Velocity) helped grade 11 and 12 students explore the concept of relative velocity. Students completed two case study questions, and then actively manipulated the speed and direction of a boat, along with the river speed, to see how these variables affect relative velocity.

The biology learning object (Groovy Genetics) was designed to help grade 11 students investigate the basics of Mendel's genetics relating the genotype (genetic trait) with the phenotype (physical traits) including monohybrid and dihybrid crosses. Students had a visual instruction to complete Punnett squares. Each activity finished with an assessment.

The chemistry learning object (Le Chatelier's Principle) demonstrated the three stresses (concentration, temperature & pressure change) that can be imposed to a system at chemical equilibrium. Students explored how equilibrium shifts related to Le Chatelier's Principle. Students assessed their learning in a simulated laboratory environment by imposing changes to equilibrated systems and predicting the correct outcome.

The computer science learning object (Logic Flows) was designed to teach grade 10 or 11 students the six basic logic operations (gates) AND, OR, NOT, XOR (exclusive OR), NOR (NOT-OR) and NAND (NOT-AND) through a visual metaphor of water flowing through pipes. Students selected the least number of inputs (water taps) needed to get a result in the single output (water holding tank) to learn the logical function of each operation.

Developing the Learning Objects

The design of the learning objects was based on the following principles. First, the learning objects were created at the grassroots level by preservice and inservice teachers. Wiley (2000) maintained that learning objects need to be sufficiently challenging, so inservice teachers were asked to brainstorm about and select areas where their students had the most difficulty. Second, the learning objects were designed to be context rich, however they focussed on a relatively specific topic areas that could be shared by different grades. Reusability, while important, took a back seat to developing meaningful and motivating problems. This approach is supported by a number of learning theorists (Brown, Collins & Duguid, 1989; Lampert, 1986; Larkin, 1989; Lave & Wenger, 1991; Sternberg, 1989). Third, the learning objects were both interactive and constructivist in nature. Students interacted with the computer, but not simply by clicking "next, next, next." They had to construct solutions to genuine problems. Fourth, the "octopus" or resource model proposed by Wiley et al., (2004) was used. The learning objects were designed to support and reinforce understanding of specific concepts. They were not designed as stand alone modules that could teach concepts. Finally, the learning objects went through many stages of development and formative evaluation, including a pilot study involving secondary school students. This approach is supported by Downes (2001) and Polsani (2003). Note that a more detailed description and analysis of the development of learning objects used in this study is offered by Kay & Knaack (2005).

Procedure

Preservice and inservice teachers administered the survey to their classes after using one of the learning objects within the context of a lesson. Students were told the purpose of the study and asked to give written consent if they wished to volunteer to participate. Teachers and teacher candidates were instructed to use the learning object as authentically as possible. Often the learning object was used as another teaching tool within the context of a unit. Students were taken to a computer lab, given some preliminary introduction to the learning object and then asked to use it. Since learning objects are best surrounded by teacher input and assistance, preservice and inservice provided help to students in need. After a one period of using the learning object (approximately 70 minutes), students were asked to fill out a survey (see Appendix A).

Data Sources

The data for this study was gathered using seven, 7-point Likert scale items and two open ended questions (see Appendix A). The questions yielded both quantitative and qualitative data.

Quantitative Data. A principal component factor analysis on the seven Likert scale items revealed two distinct constructs (Table 1). The first construct, consisted of items one to four, and was labelled "perceived benefit" of the learning object. The second construct, computer comfort rating, consisted if items five to seven. The internal reliability estimates were .87 for perceived benefit and .79 for computer comfort rating. Criterion related validity for perceived benefit score was assessed by correlating the survey score with the qualitative ratings (Item 9 – see scoring below). The correlation was significant (.64; $p < .001$).

Insert Table 1 about here.

Qualitative Data – Learning Object Quality. Item 8 (Appendix A) asked students what they liked and did not like about the learning object. A total of 757 comments were written down by 221 students. Student comments were coded based on well-established principles of instructional design. Thirteen categories are presented with examples and references in Table 2. In addition, all comments were rated on a five-point Likert scale (-2 = very negative, -1 = negative, 0 = neutral, 1 = positive, 2 = very positive).

Two raters assessed the first 100 comments made by students and achieved inter-rater reliability of .78. They then met, discussed all discrepancies and attained 100% agreement. Next the raters assessed the remaining 657 comments with an inter-rated reliability of .66. All discrepancies were reviewed and 100% agreement was reached again.

Insert Table 2 about here.

Qualitative Data – Benefits of Learning Objects. Item 9 (Appendix A) asked students whether the learning object was beneficial. Two-hundred and twenty five comments were made and categorized according to nine post-hoc categories (Table 3). 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 .72. They then met, discussed all discrepancies and attained 100% agreement.

Insert Table 3 about here.

Data

Predictor Variables. Three predictor variables were examined in this study: computer comfort rating (Items 5 to 7 in Appendix A), gender (male and female) and grade (9, 11, and 12).

Response Variables. Two main response variables were looked at: perceived benefit and quality. Perceived benefit of the learning object was measured using survey (Items 1 to 4 in Appendix A) and qualitative feedback (Item 9 – Appendix A). The quality of learning objects was assessed from qualitative feedback (Item 8 – Appendix A).

Results

Perceived Benefit of Learning Object

Based on the average perceived benefit rating from the survey (items 1 to 4 - Appendix A), it appears the students felt the learning object was more beneficial than not (M= 4.8, SD= 1.5; scale ranged from 1 to 7). Fourteen percent of all students (n=30) disagreed (average score of 3 or less) that the learning object was of benefit whereas 55% (n=122) agreed (average score of 5 or more) that it was useful.

The qualitative comments (Q9 – Appendix A) supported the survey results. Twenty-four percent of the students (n=55) felt the overall learning object was not beneficial, however 66% (n= 146) felt it did provide benefit.

A more detailed examination indicated that the motivational, interactive, and visual qualities were most important to students who benefited from the learning object. Whether they learned something new was also cited frequently and rated highly. Presenting the learning object after the topic had already been learned and poor instructions were the top two reasons given by students who did not benefit from the learning object (Table 4).

Insert Table 4 about here.

Quality of Learning Object

Overview. Students were relatively negative with respect to their comments about learning object quality (Item 8 – Appendix A). Fifty-seven percent of all comments were either very negative (n=42, 6%) or negative (n=392, 52%) whereas only 42% of the students made positive (n=258, 34%) or very positive (n=57, 8%) statements about learning object quality.

Categories. An analysis of categories evaluating learning object quality (see Table 2 for description) identified animation, interactivity, and usefulness as the highest rated areas and audio, correct information, difficulty, clarity of instructions, and help functions as the lowest rated. Table 5 provides means and standard deviation for all categories assessing the quality of learning objects.

Insert Table 5 about here.

A one-way ANOVA comparing categories of learning object quality was significant ($p < .001$). Audio, correct information, and difficulty were rated significantly lower than animations, interactivity, and usefulness (Scheffé post hoc analysis, $p < .05$).

Categories – Likes Only. One might assume that categories with mean ratings close to zero are not particularly important with respect to evaluation. However, it is possible that a mean of zero could indicate an even split between students who liked and disliked a specific category.

Therefore, it is worth looking at what students liked about the learning objects, without dislikes, to identify polar "hot spots." A comparison of means for positive comments confirmed that usefulness (*M*=1.33) was still important, but that theme and motivation (*M*=1.35), learner control (*M*=1.35), and organization of the layout (*M*=1.20) also received high ratings. These areas had mean ratings that were close to zero when negative comments were included (see Table 4). This indicates than students had relatively polar attitudes about these categories.

Categories – Dislikes Only. A comparison of means for negative comments indicated that usefulness (*M*=-1.33) remained important, however theme and motivation (*M*=-1.32) was also perceived as particularly negative. Students appeared to either like or dislike the theme or motivating qualities of the learning object.

Correlation between Quality and Perceived Benefit Scores. Theme and motivation (r=.45; $p < .01$), the organization of the layout (r=.33; $p < .01$), clear instructions (r=.33; $p < .01$), and usefulness (r=.33; $p < .01$) were significantly correlated with the perceived benefit score measured by the survey (items 1 to 4 – Appendix B).

Computer Comfort

Overview. Students in this study appeared to be relatively comfortable using computers with an average computer comfort score of 5.2 (*SD*= 1.3; scale range from 1 to 7; items 5 to 7 – Appendix A). Sixty-six percent of the students (n=146) were comfortable working with computers (average score of 5 or more) while only seven percent (n=15) were uncomfortable (average score of 3 or less).

Correlation with Perceived Benefit. The overall correlation between computer comfort and perceived benefit (survey) was high and significant ($r = .59$; $p < .001$). Computer comfort was also significantly correlated ($r = .52$; $p < .001$) with benefit ratings derived from the qualitative data ratings (Item 9 – Appendix A).

Correlation with Quality of Learning Object. Computer comfort was significantly correlated with overall ratings of learning object quality ($r = .37$; $p < .001$). An analysis of specific categories revealed that computer comfort was significantly correlated with theme/motivation (r = .38; p <.001) and clear instructions (r = .22; p <.01).

Gender

Overall. No significant differences between males and females were found with respect to perceived benefit of the learning objects (survey or qualities data), learning object quality, or computer comfort.

Perceived Benefit – Specific Categories. Independent t-tests done for gender and perceived benefit category (Table 3) revealed two significant differences. First, males (M=.97) rated the learning object higher than females (M =.63) in terms of being a good review or reinforcement of concepts (p <.05). Second, females (M=-.90) saw clarity of instructions as significantly more important than males (M=.08) with respect whether a learning object was beneficial (p <.05).

Quality –Specific Categories. An analysis of learning quality categories (Table 2) indicated that females (M=-.91) rated help feature significantly lower than males (M= .10; t=3.67, p < .005). All other categories were not significant.

Grade

Overview. A MANOVA with computer comfort score as a covariate was used to examine differences among grade levels with respect to perceived benefits and quality of learning object. Significant differences among grades were observed for perceived benefit (survey questions - $p<.005$; open ended question – no significant difference) and learning object quality ($p <.001$). An analysis of contrasts revealed that grade 9 students rated the benefits of learning objects lower than grade 12 students. Grade 9 ($p < .001$) and 11 ($p < .005$) students rated the quality of learning objects lower than grade 12 students (see Tables 6 and 7).

Insert Tables 6 and 7 about here

Perceived Benefit Rating Categories (Q9). A series of ANOVAs analysing the thirteen benefit categories (Table 2) showed no significant differences among grades.

Quality of *Learning Object.* A series of ANOVA's were run comparing mean grade ratings of categories used to assess learning object quality. While a majority of the categories showed no significant effect for grade, four areas showed significantly higher ratings by older students: learner control, graphics, clear instructions, and theme/motivation (see Table 8). These results are partially compromised because students from each grade did not experience all learning objects.

Insert Table 8 about here.

Discussion

The purpose of this study was to systematically evaluate the use of learning objects by secondary school students. A metric, based on well tested principles of instructional design, was used to examine (a) the perceived benefit of learning objects, (b) the quality of learning objects, and (c) individual differences in use.

Evaluation Tool

This study is unique in attempting to develop a reliable and valid metric to evaluate the benefits and specific impact of a wide range of learning object qualities. The perceived benefits scale proved to be reliable and valid. The quality scale was also reliable, although validity was not tested. The coding scheme (see Table 2) based on sound principles of instructional design was particularly useful in identifying salient qualities of learning objects. Overall, the evaluation tool used in this study provided a reasonable foundation with which to assess the impact of learning objects.

Further research, though, is needed to correlate specific learning qualities with actual learning outcomes.

Perceived Benefit of Learning Object

To date, the use of learning objects by secondary school students has not been formally examined. The results from his study, suggest that learning objects are a viable learning tool for this population. Two-thirds of all students felt that learning objects were beneficial, particularly when they had a motivating theme, with visual supports, and interactivity. These results are consistent with previous research on instructional design (e.g., Akpinar & Hartley, 1996; Harp & Mayer, 1998; Bagui, 1998; Druin et al. 1999; Gadanidis et al., 2003; Hanna, Risden, Czerwinski, & Alexander, 1999; Kennedy & McNaught, 1997; Oren, 1990; Sedig & Liang, submitted for publication; Stoney & Wild, 1998)

Quality of Learning Object.

The results from this paper suggest that four of the thirteen learning quality categories (Table 2) are particularly important in terms of learning object quality and benefit: usefulness, clear instructions, organization/layout, and theme/motivation. If the learning object provides clear instructions, is well organized, motivating, and perceived as being useful, secondary school students are more likely feel they have benefited from the experience. These results match the qualitative feedback reported by Cochrane (2005) and MacDonald et al. (2005) for higher education students.

Computer Comfort

Previous research behaviours (e.g., Barbeitte & Weiss, 2004; Durndell & Haag, 2002; Shapka & Ferrari, 2003; Solvberg, 2002) predicted that computer self efficacy would play a significant role in use of the learning objects evaluated in this study. This prediction was supported as computer comfort level was strongly correlated with perceived benefits and quality of the learning object. It appears that those students who did not feel comfortable with using computers did not work well with the learning objects. Educators need to be aware of this bias, however, two thirds of the 221 secondary school students in this study were comfortable with computers. Overall, the secondary school population seems predisposed to using computer instruction.

Gender

Twenty years of persistent bias in computer related behaviour in favour of males (e.g., Kay, 1992; 1993a; Whitley, 1997; Kay, submitted for publication) would have lead one to expect a similar bias with learning objects. However, there were very few gender differences for perceived quality and benefits of the learning objects used. Females were more critical of the help features and rated clarity of instructions as more important than males. Shapka & Ferrari, (2003) reported female preservice teachers were more likely to use help features than males. One could speculate that this pattern was mirrored by secondary school students. Female students may have relied on help more than males and therefore they were more critical. More in depth research needs to be done in this area.

Grade

No previous research has been done comparing grade levels and use of learning objects. Results from this study suggest that younger students rated learning objects as being poorer in quality and less beneficial than older students. This result is partially confounded by the fact that different age groups used different learning objects. For example grade 9 students used the mathematics learning objects exclusively, but this object was rated lower than some of the learning objects used by grade 11 and 12 students. It is conceivable that younger age groups are more into gaming and therefore they might be more critical of relatively simple learning objects. It is also possible that younger students might see working with computers as a game like atmosphere, whereas as older students may be more focussed in their learning. Further research needs to be done in this area.

Learning

The underlying theme in this paper is a clear emphasis on the cognitive aspects of learning objects. It is strongly felt the ultimate goal of any learning object is to help a student learn. This question was looked at indirectly by assessing the perceived quality and benefits of learning objects.

The question “Are learning objects beneficial to secondary school students?” is too simplistic given the results of this study. A better question is “Under what conditions do learning objects provide the most benefit to secondary school students?” The evidence suggests that students will benefit more if they are comfortable with computers, the learning object has a well organized layout,is interactive, visual representations are provided that make abstract concepts more concrete, instructions are clear, and the theme is fun or motivating.

Overall, secondary school students appear to be relatively receptive to using learning objects. While, almost 60% of the students were critical about one or more learning object features, roughly two thirds of all students perceived learning objects as beneficial because they were fun, interactive, visual, and helped them learn. Students who did not benefit from the learning felt that they were presented at the wrong time (e.g., after they had already learned the concept) or that the instructions were not clear enough. Interestingly, these reasons, both positive and negative, are learning focussed. While reusability, accessibility, and adaptability are given heavy emphasis in the learning object literature (Appendix B), when it comes to the end user, learning features appear to be more important.

Caveats

This study was the first attempt to systematically evaluate learning object qualities in the eyes of secondary school students. While the study produced useful information for educators and researchers, there are at least four key areas that could be improved in future research. First, a set of pre and post-test content questions is important to assess whether any learning actually occurred. Second, a more systematic survey requiring students to rate all quality and benefit categories (Tables 2 and 3) would help to provide more comprehensive assessment data. Third, details about how each learning object is used are necessary to open up a meaningful dialogue on the kinds of instructional wraps that are effective. Finally, a more detailed assessment of computer ability, attitudes, experience, and learning styles might provide insights about the effect of individual differences on the use of learning objects.

Future Research

There are numerous opportunities for future research based on a clear absence of empirical investigation in the learning object literature and the results observed in this study. These include:

- Further research in secondary schools and new research in elementary schools
- Further research in individual differences (gender, learning style, computer ability)
- Exploration on the role of context, motivation and theme in determining the impact of learning objects
- An evaluation of education applets that match many if not all of the qualities of learning objects
- Examining the role of instructional wrap or guidance on the effectiveness of learning objects

- Developing a more detailed and comprehensive evaluation scheme for assessing learning object effectiveness

Summary

The purpose of this study was to evaluate the use of learning objects by secondary school students. Clear emphasis was placed on a learning-focussed definition of learning objects, a comprehensive evaluation metric examining the quality and benefits of learning objects, and individual differences in use (computer comfort, grade level, and gender). The evaluation metric used was theoretically sound, reliable, and valid. Overall, two thirds of the students stated they benefited from using the learning object. Students benefited more if they were comfortable with computers, the learning object had a well organized layout, instructions were clear, and the theme was fun or motivating. Students appreciated the motivating, hands-on, and visual qualities of the learning objects most. Computer comfort was significantly correlated with learning object quality and benefit. Younger students appeared to have less positive experiences than the older counterparts. There were no gender differences in perceived quality or benefit of learning objects, with one exception. Females emphasized the quality of help features significantly more than males.

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Table 1

Varimax Rotated Factor Loadings on Learning Object Survey

Item	Factor 1	Factor 2
1. Another strategy	.85	
2. Understanding		.88
3. Did benefit *		.83
4. Would use again	.64	
5. Enjoy computers		.82
6. Graphics Help		.84
7. Interactive helps		.73

FACTOR	EIGENVALUE	PCT OF VAR	CUM PCT
1	4.02	57.5	57.5
2	1.05	15.0	72.5

* Reverse scoring because of negatively worded question

Table 2

Coding Scheme for Assessing Learning Object Quality (Item 8 – Appendix A)

Category & References	Criteria	Sample Student Comments
1. Organization / Layout (Calvi, 1997; Koehler & Lehrer, 1998; Lorch, 1989; Madhumita, 1995)	Refers to the location or overall layout of items on the screen	“Sometimes we didn't know where/what to click.” “I found that they were missing the next button.” “Easy to see layout” “[Use a] full screen as opposed to small box.”

2. Learner Control over Interface (Akpinar & Hartlet, 1996; Bagui, 1998; Druin et al. 1999; Hanna et al., 1999; Kennedy & McNaught, 1997)	Refers the control of the user over specific features of the learning object including pace of learning	"[I liked] that it was step by step and I could go at my own pace." "I liked being able to increase and decrease volume, temperature and pressure on my own. It made it easier to learn and understand." "It was too brief and it went too fast."
3. Animation (Gadanidis et al., 2003; Oren, 1990; Stoney & Wild, 1998; Sedig & Liang, submitted)	Refers specifically to animation features of the program	"You don't need all the animation. It's good to give something good to look at, but sometimes it can hinder progress." "I liked" the fun animations" "Like how it was linked with little movies … demonstrating techniques." "I liked the moving spaceship.

4. Graphics (Gadanidis et al., 2003; Oren, 1990; Stoney & Wild, 1998; Sedig & Liang, submitted)	Refers to graphics (non animated of the program), colours, size of text	"The pictures were immature for the age group." "I would correct several mistakes in the graphics" "The graphics and captions that explained the steps were helpful." "Change the colours to be brighter."
5. Audio (Gadanidis et al., 2003; Oren, 1990; Stoney & Wild, 1998; Sedig & Liang, submitted)	Refers to audio features	"Needed a voice to tell you what to do" "Needs sound effects" "Unable to hear the character (no sound card on computers)."

6. Clear Instructions (Acovelli et al., 1997; Jones et al., 1995; Kennedy & McNaught, 1997 ; Macdonald et al., 2005)	Refers to clarity of instructions before feedback or help is given to the user	"Some of the instruction were confusing" "I … found it helpful running it through first and showing you how to do it." "[I needed] … more explanations/Clearer instructions.
7. Help Features (Acovelli et al., 1997; Jones et al., 1995; Kennedy & McNaught, 1997; Macdonald et al., 2005)	Refers to help features of the program	"The glossary was helpful." "Help function was really good" "Wasn't very good in helping you when you were having trouble…I got more help from the teacher than it."

8. Interactivity (Akpinar & Hartley, 1996; Bagui, 1998; Druin et al. 1999; Hanna et al., 1999; Kennedy & McNaught, 1997)	Refers to general interactive nature of the program	"Using the computer helped me more for genetics because it was interactive." "I like that it is on the computer and you were able to type the answers." "I liked the interacting problems"
9. Incorrect Content / Errors	Refers to incorrect content	"There were a few errors on the sight." "In the dihybrid cross section, it showed some blond girls who should have been brunette."

10. Difficulty / Challenge Levels (Hanna et al., 1999; Klawe, 1999; Savery, 1995)	Was the program challenging? Too easy? Just the right difficulty level?	"Make it a bit more basic." "For someone who didn't know what they were doing, the first few didn't teach you anything but to drag and drop." "I didn't like how the last mission was too hard."
11. Useful / Informative (Sedig & Liang, submitted)	Refers to how useful or informative the learning object was	"I like how it helped me learn" "I found the simulations to be very useful" "[The object] has excellent review material and interesting activities." "I don't think I learned anything from it though."

12. Assessment (Atkins, 1993; Kramarski & Zeichner, 2001; Sedighian, 1998; Wiest, 2001; Zammit, 2000)	Refers to summative feedback/ evaluation given after a major task (as opposed to a single action) is completed	No specific comments offered by students
13. Theme / Motivation (Akpibar & Hartley, 1996; Harp & Mayer, 1998)	Refers to overall theme and /or motivating aspects of the learning object	"Very boring. Confusing. Frustrating." "Better than paper or lecture - game is good!" "I liked it because I enjoy using computers, and I learn better on them."

Table 3

Coding Scheme for Assessing Learning Object Benefits (Item 9 – Appendix A)

Reason Category	Criteria	Sample Student Comments
1. Timing	When the learning object was introduced in the curriculum	"I think I would have benefited more if I used this program while studying the unit." "It didn't benefit me because that particular unit was over. It would have helped better when I was first learning the concepts. "
2. Review of Basics / Reinforcement	Refers to reviewing, reinforcing concept, practice.	"going over it more times is always good for memory" "it did help me to review the concept and gave me practise in finding the equation of a line."

3. Interactive / Hands On / Learner Control	Refers to interactive nature of the process	“I believe I did, cause I got to do my own pace … I prefer more hands on things (like experiments).” “Yes, it helped because it was interactive.”
4. Good for visual learners	Refers to some visual aspect of the process	“I was able to picture how logic gates function better through using the learning object.” “I found it interesting. I need to see it”
5. Computer Based	Refers more generally to liking to work with computers	“I think that digital learning kind of made the game confusing.” “I think I somewhat did because I find working on the computer is easier then working on paper. “

6. Fun / Interesting	Refers to process being fun, interesting, motivating	“I think I learned the concepts better because it made them more interesting.” “I think I did. The learning object grasped my attention better than a teacher talking non-stop.”
7. Learning Related	Refers to some aspect of the learning process	“I don't think I learned the concept better.” “It did help me teach the concept better”
8. Clarity	Refers to the clarity of the program and/or the quality of instruction	“I think it was very confusing and hard to understand.” “Yes, this helped me. It made it much clearer and was very educational.”
9. Not good at subject	Refers to personal difficulties in subject areas	“No, to be honest it bothered me. In general I don't enjoy math and this did not help.”

10. Compare to other method	Compared to other teaching method / strategy	"Yes, because it… is better than having the teacher tell you what to do." "Would rather learn from a book."
11. No reason given		"I didn't benefit from any of it." "Yes."

Table 4

Mean Ratings for Reasons Given for Benefits of Learning Objects (Q9)

Reason	n	Mean	Std. Deviation
Fun / Interesting	17	1.35	0.74
Visual Learners	33	1.24	0.84
Interactive	30	1.17	1.34
Learning Related	37	0.81	1.13
Good Review	60	0.80	1.04
Computer Based	5	0.20	1.40
Compare to Another Method	24	0.00	1.18
Timing	21	-0.29	1.19
Clarity	33	-0.55	0.00
Not good at subject	3	-1.35	0.38

Table 5

Mean Ratings for Categories Evaluating Learning Object Quality

Category	n	Mean	Std. Deviation
Animations	27	0.81	0.74
Interactivity	47	0.66	0.84
Useful	39	0.51	1.34
Assessment	9	0.44	1.13
Graphics	84	0.25	1.04
Theme/ Motivation	125	0.12	1.40
Organization	34	-0.06	1.18
Learner Control	75	-0.12	1.19
Help Functions	42	-0.43	1.02
Clear Instructions	138	-0.61	0.95
Difficulty	107	-0.67	0.81
Information	17	-1.00	0.00

Correct			
Audio	13	-1.15	0.38

Table 6

MANOVA for Learning Object Quality, Learning Object Benefits, and Computer Comfort for Grade

Source	*df*	*SS*	*MS*	*F*	Post Hoc Analysis
Learning Quality (Q8)	2	7.1	3.5	10.55*	G12 > G11 and G9
Benefits (Scale)	2	282.5	141.3	6.38**	G12 > G9
Benefits (Q9)	2	3.3	1.7	1.81	

* $p < .001$

** $p < .005$

Table 7

Adjusted Means Scores for Learning Object and Benefits by Grade

	Learning Object Quality (Q8)		Benefit (Scale)		Benefit (Q9)	
	Mean	S.E.	Mean	S.E.	Mean	S.E.
Grade 9	-0.29[1]	0.06	17.90[1]	0.53	0.30[1]	0.11
Grade 10	-0.11[1]	0.07	19.33[1]	0.59	0.51[1]	0.12
Grade 11	0.20[1]	0.08	20.82[1]	0.62	0.61[1]	0.13

[1] Covariate (Computer Comfort) appearing in model is evaluated at 15.9

Table 8

Grade Differences Among Categories Evaluating Learning Quality

	Grade			
	9 M[1] (SD[2])	11 M (SD)	12 M (SD)	Post Hoc Comparisons
Organization	.00 (1.1)	-.29 (1.3)	.00 (1.3)	No significant difference
Learner Control	-.25 (1.2)	-.43(1.0)	.48 (1.3)	G12 > G11, G9; p <.05
Animation	1.00 (0.0)	-.55 (0.8)	1.00 (0.7)	No significant difference
Graphics	-.18 (1.1)	.50 (0.8)	.58 (1.0)	G12, G11 > G9; p <.05
Audio	-	-	-	Sample too small
Clear Instructions	-.77 (0.9)	-.72 (0.8)	-.25 (1.0)	G12 > G9; p <.05

Help Features	-.55 (1.0)	-.20 (1.1)	-.13 (0.9)	No significant difference
Interactivity	.79 (0.9)	.65 (0.8)	.65 (0.9)	No significant difference
Info. Correct	-	-	-	Sample too small
Difficulty	-.55 (1.0)	-.73 (0.7)	-.79 (0.6)	No significant difference
Useful	.18 (1.5)	1.0 (1.2)	.58 (1.2)	No significant difference
Assessment	-	-	-	Sample too small
Theme/Motivation	-.25 (1.4)	.48 (1.5)	.96 (0.9)	G12 > G9; $p<.005$

[1]Mean

[2]Standard Deviation

Appendix A - Learning Object Survey

	Strongly Disagree 1	Disagree 2	Slightly Disagree 3	Neutral 4	Slightly Agree 5	Agree 6	Strongly Agree 7
1. The learning object has some benefit in terms of providing me with another **learning strategy/another tool**.	1	2	3	4	5	6	7
2. I feel the learning object did **benefit** my **understanding** of the subject matter's concept/principle.	1	2	3	4	5	6	7
3. I **did not benefit** from using the learning object.	1	2	3	4	5	6	7
4. I am interested in using the **learning object again**.	1	2	3	4	5	6	7

5. I **enjoy working on the computer** to learn.	1	2	3	4	5	6	7
6. I find **computer graphics and interactive** programs help me learn.	1	2	3	4	5	6	7
7. I benefit from learning through **interactive & engaging** activities.	1	2	3	4	5	6	7

8. You used a digital learning object on the computer. Tell me about this experience when you used the object.

   a) What did you like? (found helpful, liked working with, what worked well for you)

   b) What didn't you like? (found confusing, or didn't like, or didn't understand)

9. Do you think you benefited from using this particular learning object? Do you think you learned the concept better? Do you think it helped you review a concept you just learned? Why? Why not?

Appendix B – Key Focus of Learning Object Papers Reviewed in the Study

	Definition	Design	Develop	Metadata	Reusable	Repository	Standards	Learning	Evaluation
Adams, et al., 2004		X	X						X
Agostinho et al., 2004	X					X		X	
Atif et al., 2003				X					
Bartz, 2002				X					
Baruque & Melo, 2004		X							
Bennett & McGee, 2005	X								
Boyle, 2003		X			X				
Bradley & Boyle, 2004		X	X						X
Butson, 2003		X						X	
Buzza et al., 2004						X			
Carey et al., 2002				X					

Christiansen & Anderson, 2004									
Cochrane, 2005		X	X					X	X
COHERE Group, 2002								X	
Collis & Strijker, 2003		X			X				
Downes, 2001				X		X			
Downes, 2003		X			X				
Duval et al., 2004				X		X		X	
Fiadihi & Mohammed, 2004		X	X	X			X		
Friesen, 2001	X								
Gadanidis et al., 2003								X	
Gibbons et al., 2000		X						X	

Hamel & Ryan-Jones, 2002		X					X		
Harmon & Koohang, 2005	X								
Jaakkola & Nurmi, 2004								X	X
Jonassen & Churchill, 2004				X	X			X	
Kenny et al., 1999		X							X
Koppi et al., 2005				X		X			
Krauss & Ally, 2005		X	X		X				X
Littlejohn, 2003		X		X	X		X		
MacDonald et al., 2005		X	X						X
Maclaren, 2004		X						X	

McGreal, 2004	X								
McReal et al., 2004						X			
Metros, 2005		X	X						
Morris, 2005			X		X				
Muzio et al., 2002		X						X	
Nesbit et al., 2002									X
Orill, 2000								X	
Paquette & Rosca, 2002		X							
Parrish, 2004	X								
Petrinjak & Graham, 2004		X	X	X					
Polsani, 2003	X		X	X	X				
Poupa & Forte, 2003				X	X				

Rehak & Mason, 2003				X	X				
Richards, 2002								X	
Richards et al., 2002						X			
Schell & Burns, 2002						X			
Sedig & Liang, submitted		X						X	
Seki et al., 2005				X					
Siquerira & Melo, 2004		X		X					
Sloep, 2003		X				X		X	
Valderrama et al., 2005				X	X		X		
Van Zele et al., 2003			X						X
Wiley et al., 2004	X	X			X				
Wiley, 2000	X	X		X			X	X	

Wilhelm & Wilde, 2005								X		
Williams, 2000									X	