Evaluating the Use of Learning Objects for Secondary School Science

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A learning object is an interactive web-based tool that supports learning by enhancing, amplifying, and guiding the cognitive processes of a learner. To date, no formal research has been done on the use of learning objects in secondary school science classrooms. The purpose of this study was to evaluate the use of learning objects developed for high school students in areas of biology, chemistry, or physics. The evaluation metric used to assess the benefits and quality of learning objects was theoretically sound, reliable, and partially validated. Two thirds of the students stated they benefited from using the learning object. Teachers confirmed that learning objects were beneficial to student learning and that they would use them again. Students benefited more if they were comfortable with computers, the content was perceived as being useful, 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 and learning object type, but not gender, were significantly related to learning object quality and benefit.

For the past 10 years, a concentrated effort has been made by educators to integrate technology into the classroom in effective and meaningful ways. The results of these efforts have been mixed at best. Part of the problem appears to be a daunting list of obstacles to using technology including: lack of time, limited skill, not understanding how to use technology effectively,
and insufficient access. Learning objects, defined as “interactive web-based tools designed to enhance, amplify and guide learning” offer a promising, albeit untested technology tool for Science teachers. Most learning objects are readily accessible over the Internet, relatively easy to learn and use, and focus on specific concepts. They are also designed to support exploration, investigation, constructing solutions, and manipulating parameters instead of memorizing and retaining a series of facts. In addition, a number of learning objects offer a graphical component that helps make abstract concepts more concrete. Finally, learning objects are adaptive, allowing users to have a certain degree of control over their learning environment. The purpose of the following study was to systematically evaluate the use of learning objects by secondary school students of biology, chemistry, and physics.

**LITERATURE REVIEW**

**Technology in the Classroom**

Considerable effort has been made by educational policy specialists, administrators, and educators to increase the use of technology in the classroom (Compton & Harwood, 2003; McRobbie, Ginn, & Stein, 2000; Plante & Beattie, 2004; U.S. Department of Education, National Center for Education Statistics, 2002). In spite of these efforts, the impact of technology on education is reportedly mixed. A number of researchers have argued that technology has had a minor or negative impact on student learning (Cuban, 2001; Roberston, 2003; Russell, Bebell, O’Dwyer, & O’Connor, 2003; Waxman, Connell, & Gray, 2002). However, several large scale meta-analyses (Baker, Gearhart, & Herman, 1994; Kozma, 2003; Kulik, 1994; Mann, Shakeshaft, Becker, & Kottkamp, 1999; Scardamalia & Bereiter, 1996; SIIA, 2000; Sivin-Kachala, 1998; Wenglinksy, 1998) have reported significant improvement in achievement scores, attitudes toward learning, and depth of understanding when computers were integrated with learning. Gains observed in these studies, though, were dependent on subject area, type of software used, specific student population, software design, educator role, and level of student access (Kulik; Sivin-Kachala).
Science and Technology in the Classroom

A review of 36 studies (Table 1) on the impact of technology in secondary school science classrooms revealed mixed results with respect to cognitive and attitudinal gains, however there were exceptions. Nine studies reported statistically significant positive results when technology was integrated into the classroom and 12 studies offered qualitative data to support the positive influence of technology, Fourteen papers reported no significant improvements as a result of technology, and only one study reported a negative effect (Table 1).

The range of technological intervention examined 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. Overall, limited research has been done examining the role of Internet resources in science education at the secondary school level (see Table 1).

It should be noted that the results reported in the literature review done for this article are partially compromised by limitations in methodology. Twenty-four out of 36 studies (67%) offered no reliable estimates for measures used to assess change and 25 (69%) presented no measure of validity.

Barriers to Using Technology

Educators have faced a considerable list of obstacles preventing the successful implementation of technology including a lack of time (Eifler, Greene, & Carroll, 2001; Wepner, Ziomek, & Tao, 2003), limited technological skill (Eifler et al.; Strudler, Archambault, Bendixen, Anderson & Weiss, 2003; Thompson, Schmidt, & Davis, 2003), fear of technology (Bullock, 2004; Doering, Hughes, & Huffman, 2003), not understanding how to integrate technology into teaching (Cuban, 2001), and insufficient access (Bartlett, 2002; Brush et al., 2003; Russell et al., 2003). The positive gains reported in 21 out of 36 studies reviewed for this article suggest that there is potential for the use of technology in secondary school science. Nonetheless, given the potential list of barriers, it is not surprising that technology has had a marginal impact in some science classrooms.
<table>
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<tr>
<th>Authors</th>
<th>Technology Category</th>
<th>Technology Used</th>
<th>Dependent Variable</th>
<th>Data Collected</th>
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<td>River Web</td>
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Individual Differences in Technology Use

Two key individual differences have been studied extensively with respect to technology use: attitudes and gender. Substantial research has been done on the effect of attitude on computer related behaviour (Barbeite & Weiss, 2004; Christensen & Knezek, 2000; Durndell & Haag, 2002; Kay, 1989, 1993b; Liu, Hsieh, Cho, & Schallert, 2006; 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 shown to be particularly influential on knowledge and use of computers (e.g., Barbeite & Weiss, 2004; Durndell & Haag, 2002; Shapka & Ferrari, 2003; Solvberg, 2002).

In 1992, the author 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 (Kay, 1992, 1993a), the overall picture indicated that males had more positive attitudes, higher ability, and more frequent patterns of use. Five years later, a meta-analysis by Whitley (1997) revealed that 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, 2006), differences between males and females appeared be lessening somewhat, although male dominance was still prevalent with respect to attitude, ability, and use.

It is interesting to note that only six out of the 36 papers reviewed for this study looked at individual differences including age (Kiboss et al., 2004; Wishart & Blease, 1999), gender (Chen et al., 1999; Chiu, 2002), and ethnicity (Azvedo et al., 2004; Chen et al., 1999; Penuel et al., 2004). No studies looked at computer comfort level or self-efficacy.

The Role of Learning Objects

Learning objects are defined in this article as “interactive web-based tools that support learning by enhancing, amplifying, and guiding the cognitive processes of learners” (Metros, 2005; McGreal, 2004; Parrish, 2004; Wiley, 2000; Wiley et al. 2004). Examples of learning objects can be found at Learn Alberta, the Learning Federation, the Ideas website, and UOIT (http://education.uoit.ca/lordec/sci.html for links to all of these collections). These tools offer a number of key components that can reduce the impact of
potential obstacles observed by science teachers (e.g., accessibility, ease of use, reusability) and enhance student learning (e.g., 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; U.S. 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 (Agostinho, Bennett, & Lockyear & Harper, 2004; Duval, Hodgins, Rehak, & Robson, 2004).

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. This constructivist-based model is well documented in the literature (Albanese & Mitchell, 1993; Bruner, 1986; Carroll, 1990; 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, 2006). Finally, learning objects are adaptive, allowing users to have a certain degree of control over their learning environments (e.g., when they are learning and for how long).

In spite of the 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 in the secondary school science classroom.
Evaluating the Use of Learning Objects for Secondary School Science

Purpose

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

1. What were the reported benefits of using the learning objects (learning object benefits)?
2. What did students like and dislike about using learning objects (learning object quality)?
3. Were there individual differences (computer comfort level and gender) with respect to the perceived benefits and assessment of quality?

METHOD

Sample

Students. The sample consisted of 111 secondary school students (51 males, 59 females, one subject with missing gender data), 13 to 17 years of age, in grades nine \( (n=9) \), 11 \( (n=45) \), and 12 \( (n=55) \) (two subjects with missing grade data), enrolled in academic-focused classes from seven different suburban high schools and three boards of education. The students were obtained through convenience sampling.

Teachers. A total of 19 teachers (6 experienced, 13 preservice) participated in the development of the learning objects. Experienced teachers had taught for 10 or more years. Preservice teachers had completed at least a B.A. or B.S. 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), and five for physics (one experienced, four preservice).

Learning objects. Three learning objects in three different subject areas were evaluated by secondary school students. Thirty-four students used the biology learning objects (grades 9 and 11), 37 used the chemistry learning objects (grade 12), and 40 used the physics learning objects (grades 11 and 12).

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

The biology learning object (Mendelian Genetics) was designed to help 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, and pressure change) that can be imposed to a system at chemical equilibrium. Students explored and assessed their learning in a simulated laboratory environment by imposing changes to equilibrated systems and predicting the correct outcome.

The physics learning object (Relative Velocity) helped 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 affected relative velocity.

**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 pre-service 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 area 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; 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 (Kay, 2007; Kay & Knaack, 2005).
Procedure

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 a preliminary introduction to the learning object, and then asked to use it. Since learning objects are best surrounded by teacher input and assistance, help was provided to students in need. After 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 from students using seven, 7-point Likert scale items and two open ended questions (see Appendix A). The questions yielded both quantitative and qualitative data. A similar 5-item Likert survey was given to teachers who used the learning objects in their classrooms (see Appendix B). A detailed review and analysis of the evaluation tool used in this study is presented in Kay (2007) and Kay and Knaack (2005).

Quantitative data—Learning object benefit and computer comfort. A principal components analysis on the seven Likert scale items (student survey – Appendix A) revealed two distinct constructs (Table 2). The first construct, consisted of items one to four, and was labelled “learning object benefit.” The second construct, computer comfort rating, consisted of items five to seven. The internal reliability estimates were .87 for learning object benefit and .79 for computer comfort rating. Criterion related validity for learning object benefit score was assessed by correlating the survey score with the qualitative ratings (Item 9 – see scoring later). The correlation was significant (.64; p <.001).
Table 2
Varimax Rotated Factor Loadings on Learning Object Survey

<table>
<thead>
<tr>
<th>Item</th>
<th>Factor 1</th>
<th>Factor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Another strategy</td>
<td>.85</td>
<td></td>
</tr>
<tr>
<td>2. Understanding</td>
<td>.88</td>
<td></td>
</tr>
<tr>
<td>3. Did benefit *</td>
<td>.83</td>
<td></td>
</tr>
<tr>
<td>4. Would use again</td>
<td>.64</td>
<td></td>
</tr>
<tr>
<td>5. Enjoy computers</td>
<td></td>
<td>.82</td>
</tr>
<tr>
<td>6. Graphics Help</td>
<td></td>
<td>.84</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>EIGENVALUE</th>
<th>PCT OF VAR</th>
<th>CUM PCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.02</td>
<td>57.5</td>
<td>57.5</td>
</tr>
<tr>
<td>2</td>
<td>1.05</td>
<td>15.0</td>
<td>72.5</td>
</tr>
</tbody>
</table>

* Reverse scoring because of negatively worded question

**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 333 comments were written down by 111 students. Student comments were coded based on well-established principles of instructional design. Thirteen categories are presented with examples and references in Kay (2007) and Kay and Knaack (2005). In addition, all comments were rated on a 5-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 0.78. They then met, discussed all discrepancies and attained 100% agreement. Next the raters assessed the remaining 233 comments with an inter-rated reliability of 0.66. All discrepancies were reviewed and 100% agreement was reached again.

**Qualitative data—Learning object benefit.** Item 9 (Appendix A) asked students whether the learning object was beneficial. One hundred and twenty comments were made and categorized according to nine post-hoc categories (see Kay, 2007; Kay & Knaack, 2005 for detailed review). Each comment was then rated on a 5-point Likert scale (-2 = very negative, -1 = negative, 0 = neutral, 1 = positive, 2 = very positive). Two raters assessed all comments made by students and achieved inter-rater reliability of 0.72. They then met, discussed all discrepancies and attained 100% agreement.
Data

The key variables used to evaluate learning objects in this study were:

1. learning object benefit (student survey construct of 4 items – Appendix A)
2. learning object benefit (content analysis of open-ended question based on post hoc structured categories – see Kay, 2007; Kay & Knaack, 2005)
3. learning object benefit (teacher survey – Appendix B)
4. learning object quality (content analysis of open ended response question based on 13 principles of instruction design – see Kay, 2007; Kay & Knaack, 2005)
5. learning object type (biology, chemistry, physics)

RESULTS

Learning Object Benefit

Students. Based on the average learning object benefit rating from the survey (items 1 to 4 - Appendix A), it appears the students felt the learning object was more beneficial than not ($M= 5.1$, $SD= 1.5$; scale ranged from 1 to 7). Only 11% of all students ($n=12$) disagreed (average score of 3 or less) that the learning object was of benefit whereas 67% ($n=74$) agreed (average score of 5 or more) that it was beneficial.

The qualitative comments (Q9 – Appendix A) supported the survey results. Twenty-two percent (22%; $n=21$) of student comments about the learning objects were negative, whereas 67% ($n=65$) of the comments were positive.

Being fun or interesting, interactive, visual, and learning related were the highest rated reasons given by students who reported that they had benefited from the learning object. A number of students also believed that using the learning object provided a good review. On the other hand, preference for other methods (comparing), lack of clarity in instructions, and presenting the learning object after a topic had already been learned were the top three reasons given by students who did not benefit from the learning object (Table 3).
Table 3

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

<table>
<thead>
<tr>
<th>Reason</th>
<th>n</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fun / Interesting</td>
<td>5</td>
<td>1.60</td>
<td>0.55</td>
</tr>
<tr>
<td>Visual Learners</td>
<td>22</td>
<td>1.23</td>
<td>0.53</td>
</tr>
<tr>
<td>Interactive</td>
<td>16</td>
<td>1.13</td>
<td>0.34</td>
</tr>
<tr>
<td>Learning Related</td>
<td>15</td>
<td>0.80</td>
<td>1.21</td>
</tr>
<tr>
<td>Computer Based</td>
<td>1</td>
<td>1.00</td>
<td>-</td>
</tr>
<tr>
<td>Good Review</td>
<td>22</td>
<td>0.73</td>
<td>0.55</td>
</tr>
<tr>
<td>Timing</td>
<td>12</td>
<td>-0.25</td>
<td>0.75</td>
</tr>
<tr>
<td>Clarity</td>
<td>16</td>
<td>-0.44</td>
<td>1.63</td>
</tr>
<tr>
<td>Compare to Another Method</td>
<td>11</td>
<td>-0.45</td>
<td>1.18</td>
</tr>
</tbody>
</table>

Teachers. Overall, experienced and preservice teachers strongly agreed that using learning objects was a beneficial strategy for students (Item 1 - $M=6.6$, $SD=0.51$), one that they would be interested in using again in their classrooms (Item 3 - $M=6.6$, $SD=0.50$). The teachers also agreed that the learning object helped students understand concepts ($M=5.5$, $SD=1.15$) and anticipated that students would want to use learning objects again ($M=5.7$, $SD=1.62$). Most teachers noted that the learning objects would have been more successful if they had been implemented at the right time in the curriculum ($M=6.2$, $SD=1.05$). Recall, that the learning objects were used during the field experience placements and may not have been introduced at a pedagogically appropriate time.

Learning Object Quality

Overview. Students were divided with respect to their comments about learning object quality (Item 8 – Appendix A). Fifty-three percent (53%) of all comments were either very negative ($n=10$, 3%) or negative ($n=169$, 50%) whereas 46% of the students made positive ($n=130$, 39%) or very positive ($n=23$, 7%) statements about learning object quality.

Categories. An analysis of categories evaluating learning object quality identified animation, interactivity, usefulness, and assessment as the highest rated areas and audio, correctness of information, and difficulty level (either too low of too high) as the lowest rated. Table 4 provides means and standard deviation for all categories assessing the quality of learning objects.
Table 4

<table>
<thead>
<tr>
<th>Category</th>
<th>n</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animations</td>
<td>21</td>
<td>0.76</td>
<td>0.83</td>
</tr>
<tr>
<td>Interactivity</td>
<td>29</td>
<td>0.72</td>
<td>0.70</td>
</tr>
<tr>
<td>Useful</td>
<td>20</td>
<td>0.60</td>
<td>1.27</td>
</tr>
<tr>
<td>Assessment</td>
<td>7</td>
<td>0.57</td>
<td>1.13</td>
</tr>
<tr>
<td>Graphics</td>
<td>42</td>
<td>0.48</td>
<td>0.92</td>
</tr>
<tr>
<td>Theme/ Motivation</td>
<td>29</td>
<td>0.21</td>
<td>1.35</td>
</tr>
<tr>
<td>Learner Control</td>
<td>46</td>
<td>-0.04</td>
<td>1.19</td>
</tr>
<tr>
<td>Organization</td>
<td>15</td>
<td>-0.27</td>
<td>1.28</td>
</tr>
<tr>
<td>Help Functions</td>
<td>9</td>
<td>-0.33</td>
<td>1.00</td>
</tr>
<tr>
<td>Clear Instructions</td>
<td>64</td>
<td>-0.45</td>
<td>0.98</td>
</tr>
<tr>
<td>Difficulty</td>
<td>30</td>
<td>-0.97</td>
<td>0.40</td>
</tr>
<tr>
<td>Information Correct</td>
<td>10</td>
<td>-1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Audio</td>
<td>11</td>
<td>-1.18</td>
<td>0.38</td>
</tr>
</tbody>
</table>

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 animations ($M=1.12; SD=0.33$), interactivity ($M=1.00; SD=0.00$), and usefulness ($M=1.36; SD=0.50$) were still important, but that theme and motivation ($M=1.31, SD = 0.48$), learner control ($M=1.25, SD = 0.44$), and organization of the layout ($M=1.40, SD = 0.55$) 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.

Correlation between learning object quality and benefit scores. Usefulness ($r=.51; p < .001$), theme/motivation ($r=.46; p < .001$), clear instructions ($r=.34; p < .001$), and learner control ($r=.31; p < .01$) were significantly correlated with the learning object benefit score measured in the student survey (items 1 to 4 – Appendix A). In other words, when a learning object was rated highly with respect to usefulness, motivation, clarity of instructions, and learner control, it was perceived as being significantly more beneficial to learning.
Computer Comfort

Overview. Students in this study appeared to be relatively comfortable using computers with an average computer comfort score of 5.3 (SD= 1.3; scale range from 1 to 7; items 5 to 7 – Appendix A). Sixty-eight percent (68%) of the students (n=75) were comfortable working with computers (average score of 5 or more), while only 6% (n=7) were uncomfortable (average score of 3 or less).

Correlation with learning object benefit. The overall correlation between computer comfort and perceived benefit (survey) was high and significant (r = .60; p < .001). Computer comfort was also significantly correlated (r = .59; p < .001) with benefit ratings derived from the coded qualitative data (Item 9 – Appendix A).

Correlation with learning object quality. Computer comfort was significantly correlated with overall ratings of learning object quality (r = .42; p < .001; Q8 from Appendix A). An analysis of specific categories revealed that computer comfort was significantly correlated with theme/motivation (r = .41; p < .05) and clear instructions (r = .29; p < .05).

Gender

Overall. A MANOVA was run comparing males and females on four different dependent variables. Given that the number of males (n=45) and females (n=50) were not equal, Levine’s test for equality of variance was run and revealed that male and female sample populations were homogenous. Hotelling’s T2 s test revealed no significant difference between males and females with respect to learning object benefit (survey – F= 0.12, p = .74, n.s. and content analysis - F= 0.39, p = .53, n.s.), learning object quality (F= 0.16, p = .69, n.s.), and computer comfort F= 0.92, p = .34, n.s.).

DISCUSSION

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

Previous research on the use of technology in the science classroom has been compromised by weak methodology with respect to instrument reliability and validity. The learning object benefit scale in the current study proved to be reliable and valid. The learning object quality scale was also reliable, although validity was not tested. The coding scheme (see Kay, 2007; Kay & Knaack, 2005 for detailed review) was based on sound principles of instructional design and 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.

Learning Object Benefit

To date, the use of learning objects by secondary school students in the science classroom has not been formally examined. The results from this study suggest that learning objects are viable learning tools for this population. Two-thirds of all students felt that learning objects were beneficial, particularly when the learning objects had a motivating theme, with visual supports, and interactivity to support learning. These results are consistent with previous research on instructional design (Gadanidis et al., 2003; Hanna, Risden, Czerwinski, & Alexander, 1999; Kennedy & McNaught, 1997; Sedig & Liang, 2006). While student ratings might be considered specious, teachers who used the learning objects as an educational aid in this study were also very positive regarding the benefits of learning objects and most reported that they would use them again.

Learning Object Quality

Four of the 13 learning object qualities assessed were particularly important: usefulness, theme/motivation; clear instructions, and learner control. If the learning object provided clear instructions, good learner control, a motivating theme, and useful information, secondary school science students were more likely to 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.
Subjects rated six other learning object attributes either positively (animation, interactivity, and organization of layout) or negatively (difficulty level, incorrect information, and audio features), however, these characteristics were not significantly related to perceived benefit. In other words, these qualities were duly noted by students, but did not appear to affect the overall learning process.

**Computer Comfort**

Previous research on self-efficacy and computer behaviour (Barbeite & Weiss, 2004; Durndell & Haag, 2002; Shapka & Ferrari, 2003; Solvberg, 2002) predicted that computer comfort 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 learning object benefit and quality. 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 negative bias, however, two thirds of the 111 secondary school students in this study were comfortable with computers. Overall, the secondary school science population seems predisposed to using computer instruction.

**Gender**

Twenty years of persistent bias in computer-related behaviour in favour of males (Kay, 1992; 1993a; Whitley, 1997; Kay, 2006) would have lead one to expect a similar bias with learning objects. However, no gender differences were reported with respect to learning object benefit, learning object quality, and computer comfort level. It is possible that the ease of using learning objects partially limited gender differences. It is also conceivable that the population examined in this study, namely adolescent science students, may be representative of the new trend citing fewer gender differences (Kay, 2006).

**Learning**

The underlying theme in this article is a clear emphasis on the cognitive aspects of learning objects. It is strongly felt the ultimate goal of any learn-
ing 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 learning science?” 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 science students?” The evidence suggests that students will benefit more if they are comfortable with computers and the learning object offers good learner control, useful content, clear instructions, and a motivating theme. Gender appears to be an irrelevant influence.

Overall, secondary school science students appear to be receptive to using learning objects. While 53% 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 perceived learning objects as less beneficial preferred other teaching strategies, felt that the learning objects were presented at the wrong time, and/or noted that instructions within the learning object were not clear enough.

Caveats

This study was the first attempt to systematically evaluate the use of learning objects for secondary school science students. While the study produced useful information for educators and researchers, there are at least four key areas that could be addressed in future research. First, a set of pre and posttest questions is important to assess whether any learning actually occurred. Second, a more systematic survey requiring students to rate all quality and benefit categories 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.

Summary

The purpose of this study was to evaluate the use of learning objects by secondary school science students. Emphasis was placed on a pedagogically-focused definition of learning objects, a comprehensive evaluation
metric examining the quality and benefits of learning objects, and individual differences in use (computer comfort, gender, and learning object type). The evaluation metric used was theoretically sound, reliable, and partially validated. Overall, two thirds of the students stated they benefited from using the learning object. Teachers corroborated student reports noting that the learning objects were highly beneficial to learning and that they would use them again in their science classrooms. Students benefited more if they were comfortable with computers, the content was perceived as being useful, 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, but not gender, was significantly related to learning object quality and benefit.

References


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 - Learning Object Survey for Teachers

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Slightly Disagree</th>
<th>Neutral</th>
<th>Slightly Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The learning object has benefit in terms of providing students with another <strong>learning strategy</strong> in my classroom.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>2. The learning object did benefit my students in terms of their <strong>understanding of the concept/principle</strong> explored in the learning object.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>3. I would be interested in <strong>using the learning object again</strong> in my class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>4. There would have been more success with the learning object had it been <strong>implemented during the proper time</strong> within the unit.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>5. Students were interested in using the <strong>learning object again</strong>.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>