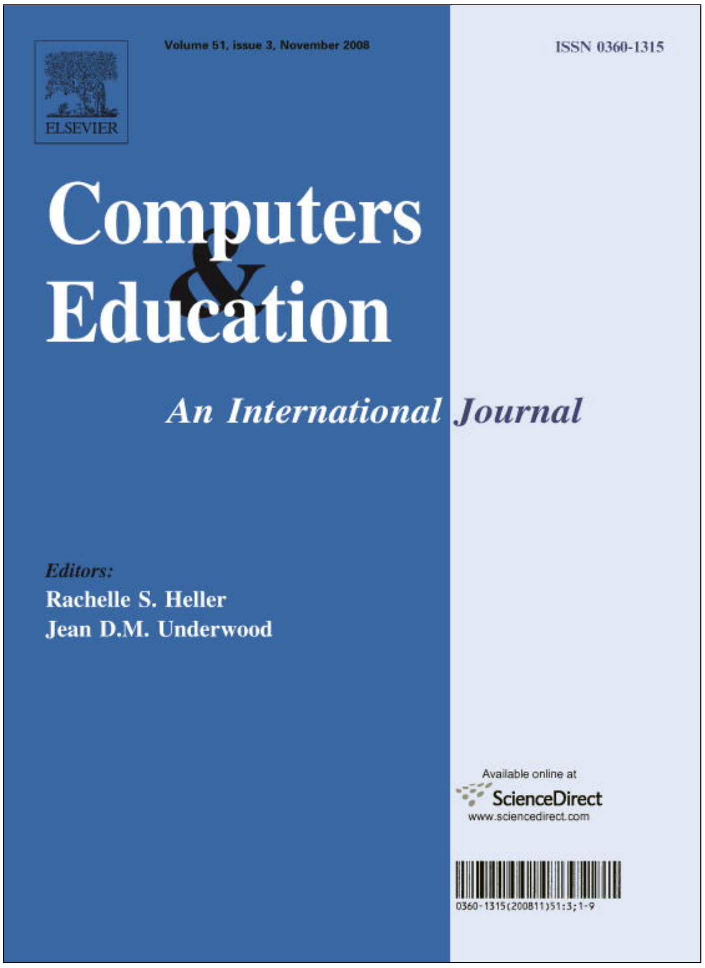
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A formative analysis of individual differences in the effectiveness of learning objects in secondary school

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Abstract

The purpose of this study was to examine individual differences in the effectiveness of learning objects in secondary school classrooms. Specifically, gender, age, grade, subject area, and computer comfort (self-efficacy) were examined in 850 students. Effectiveness was measured in terms of student attitude (learning, quality, and engagement) and student performance. No gender differences were observed between males and females with respect to student attitudes or performance. Age was significantly correlated with student attitudes and performance, however correlation coefficients were small. Grade 12 students were more positive about learning objects and performed better than grade 9 and 10 students. Science students had significantly more positive attitudes and performed better than mathematics students. Finally, students who were more comfortable about computers, appreciated learning objects more than their less confident peers, however performance was unaffected.

Keywords: Evaluate; Assess; Quality; Scale; Gender; Self-efficacy; Confidence; Age; Individual differences; Secondary school; High school; Learning object

1. Literature review

Learning objects, defined in this study as "interactive web-based tools that support learning by enhancing, amplifying, and guiding the cognitive processes of learners" (Kay & Knaack, 2007b), have been analysed from numerous perspectives. Researchers have focussed on definition (e.g., Wiley et al., 2004), design (e.g., MacDonald et al., 2005), development (e.g., Kay & Knaack, 2005), instructional wrap (e.g., Bradley & Boyle, 2004), metadata (e.g., Downes, 2004), reuse (e.g., Collis & Strijker, 2004), repositories (e.g., Cafolla, 2006), technical standards (e.g., Duval & Hodgins, 2006), learning potential (e.g., Gadanidis, Sedig, & Liang, 2004), evaluation (Kay & Knaack, 2007c), and use (Nurmi & Jaakkola, 2006). One area that has been largely overlooked is individual differences in effectiveness. It is reasonable that this omission has occurred given that the investigation of learning objects is relatively new. It is difficult, for example to understand individual

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differences when there is no clear definition, design process, or when there is no consistent model for evaluation. As some of the foundational questions are beginning to be answered, delving into the individual variations that may occur with respect to using these tools seems a natural next step. Previous research on individual differences in other areas of computer behaviour has provided useful information with respect to the impact of gender, grade level or age, self-efficacy, attitudes, and ability. It is argued that this kind of research has the potential to offer insight into the use of learning objects as well.

1.1. Impact of learning objects

Research looking at the overall impact of learning objects on teacher attitudes, student attitudes, and student learning performance has been almost uniformly positive. Teachers feel that learning objects compliment their curriculum well (Bradley & Boyle, 2004), students are more engaged (Clarke, 2006a, 2006b; De Salas & Ellis, 2006; Kay & Knaack, 2007d) and performance increases (Clarke, 2006a, 2006b; De Salas & Ellis, 2006; Kay & Knaack, 2007d). Students report liking learning objects because they are (a) fun and enjoyable, (b) easy to control with respect to the pace of learning, (c) provided timely feedback, (d) consisted of a number multimedia tools, and (e) helped them learn (Bradley & Boyle, 2004; Clarke, 2006a, 2006b; De Salas & Ellis, 2006; Docherty, Hoy, Topp, & Trinder, 2005; Kenny, Andrews, Vignola, Schilz, & Covert, 1999; Lim, Lee, & Richards, 2006; MacDonald et al., 2005; Mason, Pegler, & Weller, 2005; Reimer & Moyer, 2005; Schoner, Buzza, Harrigan, & Strampel, 2005). Finally, student performance appears to improve when learning objects are used (Akpinar & Bal, 2006; Bower, 2005; Docherty et al., 2005; Kong & Kwok, 2005; Liu & Bera, 2005; Nurmi & Jaakkola, 2006; Reimer & Moyer, 2005; Rieber, Tzeng, & Tribble, 2004; Windschitl & Andre, 1998).

Clearly, learning objects offer positive educational opportunities for teachers and students, however, we know very little about individual differences in impact. For example, we have no idea whether learning objects are effective for both male and female students. If these tools were bias in favour of one gender, we would have to reconsider their use in the classroom. Another possibility might be that learning objects, traditionally designed for students in higher education, may not work as well for students at lower grade levels. It may also be the case that younger students are not mature enough to engage in the kind of self-guided discovery required by some learning objects. Finally, computer confidence or self-efficacy could influence the effectiveness of learning objects. Students who are more comfortable with computers may react well to these tools – more anxious students may be inhibited and perform more poorly.

In summary, we would be remiss in not entering into research on individual differences in the use and effectiveness of learning objects. Understanding individual differences should provide richer insights into the impact of learning objects.

1.2. Individual differences in computer related behaviour

It is worth looking into general technology research to explore the kinds of factors that could influence computer related behaviour. Four major themes have emerged with respect to individual differences over the past 20 years: gender, age, attitude (comfort level), and ability.

1.2.1. Gender

Numerous studies have investigated the role of gender in computer behaviour (see AAUW, 2000; Barker & Aspray, 2006; Kay, 1992; Sanders, 2006; Whitley, 1997 for detailed reviews of the literature) and the following conclusions can be made. First, most studies have looked at computer attitude, ability, and/or use. Second, roughly 30–50% of the studies report differences in favour of males, 10–15% in favour of females, and 40–60% no difference. Third, differences reported, while statistically significant, are often small. Overall, one could say there is a persistent pattern of small differences in computer attitude, ability, and use that favours males, however considerable variability exists (Kay, in press).

1.2.2. Age and grade

A number of researchers have examined differences in computer attitude and ability between various age groups, albeit in a somewhat patchwork manner. Older students (15–16 years old), for example, viewed computers as tools for accomplishing tasks and getting work done (e.g., word processing, programming, use of the Internet, and email), whereas younger students (11–12 years old) saw computers as a source of enjoyment (e.g., play games and use graphics software) (Colley, 2003; Colley & Comber, 2003; Comber, Colley, Hargreaves, & Dorn, 1997).

Grimes, Hough, and Signorella (2007) looked at a larger age range and reported that working age adults used computers more and spent more hours online than either college students or retirees. Zhang (2005) added that younger employees felt the internet was more useful than older age groups. On the other hand, Harris and Grandgenett (1996) and Kubek, Miller-Albrecht, and Murphy (1999) observed that age had a negligible affect on computer attitudes.

Grade has not been looked at extensively, although one study reported that grade 11 students were less anxious than grade seven and nine students (King, Bond, & Blandford, 2002). More research needs to be done in this area, particularly in teasing out the differential impact of age and grade. It is unclear whether differences observed in computer related behaviour are a result of advances in cognitive and emotional maturity (age) or whether they are due to the cultural biases that may emerge at certain grade levels.

1.2.3. Subject area

No studies could be found looking at individual differences in the computer behaviour as a result of subject taught, although several researchers have examined the use of computers in mathematics (e.g., Forgasz, 2006) or science classes (e.g., MacKinnon, 2001). The impact of subject area on computer attitude and performance, then, is unknown.

1.2.4. Computer comfort

Considerable research has been done looking at the effect of attitude on computer related behaviour (Barbeite & Weiss, 2004; Christensen & Knezek, 2000; Durndell & Haag, 2002; Kay, 1989, 1993; Liu, Hsieh, Cho, & Schallert, 2006; Torkzadeh, Pflughoeft, & Hall, 1999). As one might predict, more positive computer attitudes are generally 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).

1.2.5. Computer ability

Computer ability has been studied extensively and there is evidence to suggest that it is related to computer attitudes (e.g., Garland & Noyes, 2004), computer anxiety (e.g., Wilfong, 2006), emotions expressed while learning (Kay, 2007), frequency of computer use (Forgasz, 2006; Lowerison, Sclater, Schmid, & Abrami, 2006), and performance (Hasan & Ali, 2004; O'Dwyer, Russell, Bebell, & Tucker-Seeley, 2005; Shih, Munoz, & Sanchez, 2006). Research looking at the effect of one's ability in a specific subject area and the successful use of computers is far less prevalent.

1.3. Individual differences with respect to learning objects

A content analysis of 183 peer-reviewed articles focussing on learning objects revealed only seven papers that referred to individual differences, albeit as a footnote in most cases. Only one of those studies looked at a secondary school population (Kay & Knaack, 2007d). Five key areas were investigated in the seven papers found: gender, grade level, computer self-efficacy, subject ability, and learning style. With respect to gender, Kay and Knaack (2007d) and Lim et al. (2006) found no marked individual differences between male and female attitudes toward learning objects. Regarding, grade level, Kay and Knaack (2007d) observed that grade 12 students rated the benefits and quality of learning objects higher than grade 9 students. De Salas and Ellis (2006) added that second and 3rd year university students were far more open to using learning objects than first year students. Concerning, computer self-efficacy, Kay and Knaack (2005) reported a significant correlation between computer comfort level and the rating of learning object benefits and quality. Lim et al. (2006) reported that students of tutors who were not comfortable with computers used learning objects less. In the area of ability, Kong and Kwok (2005) found that medium and high ability mathematics students outperformed low ability mathematics students when using learning objects, but that they used the same features. Finally, with respect to learning style, epistemological beliefs and preferences for interactivity influenced engagement and performance while using learning objects.

The collage of results reported to date with respect to individual differences and learning objects suggests that a more systematic effort is needed to develop a clearer knowledge base of what influence attitudes and performance when learning objects are used.

1.4. Purpose

The purpose of this study was to examine individual differences in the impact of learning objects in secondary school classrooms. Specifically, gender, age, grade, subject area, and computer comfort were examined.

2. Method

2.1. Overview

A broad review of methods used to evaluate learning objects offers at least five noteworthy observations.

First, the overwhelming majority of studies on learning objects have focussed on higher education. Learning objects were originally targeted at tertiary education, and use in secondary schools requires further analysis.

Second, the majority of evaluation papers focus on a single learning object (Adams, Lubega, Walmsley, & Williams, 2004; Bradley & Boyle, 2004; Kenny et al., 1999; Krauss & Ally, 2005; MacDonald et al., 2005). It is difficult to determine whether the results observed in one study are idiosyncratic or generalize to the full range of learning objects that are available.

Third, sample populations tested in many studies have been noticeably small and poorly described (e.g., Adams et al., 2004; Cochrane, 2005; Krauss & Ally, 2005; MacDonald et al., 2005; Van Zele, Vandaele, Botteldooren, & Lenaerts, 2003) making it challenging to extend any conclusions to a larger population.

Fourth, while many studies reported that students benefited from using learning objects, the evidence is often based on loosely designed assessment tools with unknown validity or reliability (Bradley & Boyle, 2004; Howard-Rose & Harrigan, 2003; Kenny et al., 1999; Krauss & Ally, 2005; Lopez-Morteo & Lopez, 2007; Schoner et al., 2005; Vacik, Wolfslehner, Spork, & Kortschak, 2006; Van Zele et al., 2003; Vargo, Nesbit, Belfer, & Archambault, 2002). As well, few evaluation studies (e.g., Kay & Knaack, 2007b, 2007d; Kenny et al., 1999; Van Zele et al., 2003) use formal statistics. The lack of reliability and validity of evaluation tools combined with an absence of statistical rigour reduce confidence in the results presented to date.

Finally, a promising trend in learning object evaluation research is the inclusion of performance measures (e.g., Adams et al., 2004; Bradley & Boyle, 2004; Docherty et al., 2005; MacDonald et al., 2005; Nurmi & Jaakkola, 2006). Until recently, there has been little evidence to support the usefulness or pedagogical impact of learning objects. The next step is to refine current evaluation tools to determine which specific qualities of learning objects influence performance.

In summary, previous methods used to evaluate learning objects are limited with respect to sample size, representative populations, reliability and validity of data collection tools, and use of formal statistics. This study attempts to address each of the methodological issues discussed.

2.2. Sample

2.2.1. Students

The student sample consisted of 850 secondary school students (444 males, 406 females), 10–22 years of age ($M = 16.5$, $SD = 1.1$). The population base spanned three separate boards of education, 15 secondary schools, and 53 different classrooms. The students were selected through convenience sampling and had to obtain signed parental permission to participate.

2.2.2. Teachers

The teacher sample consisted of 27 teachers (12 males, 15 females) and 53 classrooms (a number of teachers used learning objects more than once). Teaching experience ranged from 1 to 33 years with a mean of 9.2

(SD = 8.2). Subject areas taught were science (biology, chemistry, general science, physics, $n = 15$), math ($n = 10$), and social science (geography, history, $n = 2$). A majority of the teachers rated their ability to use computers as strong or very strong ($n = 23$) and their attitude toward using computers as positive or very positive ($n = 23$). In spite of the high computer ability and positive attitudes, only six of the teachers used computers in their classrooms more than once a month.

2.2.3. 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 35 unique learning objects were selected covering concepts in biology, Canadian history, chemistry, general science, geography, mathematics, and physics (see Appendix A).

2.3. 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.

2.4. Data sources

2.4.1. Explanatory variables

Five explanatory variables were examined in this study: gender (male, female), age, grade level (9, 10, 11, and 12), subject area taught (math, science, social science) and computer comfort (self-efficacy).

Computer comfort was assessed using a scale developed by Kay and Knaack (2005) which should good construct validity and high reliability. The internal reliability for the scale used in this study was 0.81.

2.4.2. Dependent variables

Four dependent variables were chosen for this study and included student perception of learning, quality, and engagement as well as student performance. Student self-assessment of learning, quality, and engagement was collected using the Learning Object Evaluation Scale for Students (LOES-S). These constructs were selected based on a detailed review of the learning object literature over the past 10 years (Kay & Knaack, 2007a). According to Kay and Knaack (2007a), the LOES-S displayed good reliability, construct validity, convergent validity, and predictive validity (see Appendix B for the LOES-S scale).

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

2.5. Key questions and data analysis

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

1. Are their gender differences with respect to student perceptions of learning, quality, and engagement for learning objects?
2. Are there gender differences with respect to student performance?
3. Are their age differences with respect to student perceptions of learning, quality, and engagement for learning objects?
4. Are there age differences with respect to student performance?

5. Are their grade differences with respect to student perceptions of learning, quality, and engagement for learning objects?
6. Are there grade differences with respect to student performance?
7. Are their subject differences with respect to student perceptions of learning, quality, and engagement for learning objects?
8. Are there subject differences with respect to student performance?
9. Does computer comfort have an impact on student perceptions of learning, quality, and engagement for learning objects? and
10. Does computer comfort have an impact on student performance?

3. Results

3.1. Overall variability

Before looking at specific sources that might contribute to explaining variability in learning, quality, engagement, and student performance, it is worth examining the overall variability within specific secondary school classrooms. Appendix C provides the full range of scores for all four dependent variables in classrooms where pre- and post-tests matched each other with respect to content. It is clear from this table that within each classroom, there is considerable range in scores among students. For all three survey scale items, students within the same classroom differed markedly with respect to their perceptions of learning gains (average range of 10–23), learning object quality (average range of 10–19), and how much they were engaged (average range of 6–14). Furthermore, there was wide variability in how well students performed with an average change in test scores ranging from a drop of 12% to a gain of 54%.

3.2. Gender differences

A MANOVA was run for gender and the LOES-S constructs (learning, quality, and engagement) and revealed no significant difference between male and female students. In addition, a *t*-test showed no significant gender differences with respect to student performance (see Table 1).

3.3. Age differences

Correlations among age and perceived learning ($r = 0.12 \pm 0.07$, $p < .001$), quality ($r = 0.14 \pm 0.07$, $p < .001$), and engagement ($r = 0.09 \pm 0.07$, $p < .005$) were significant. Age and student performance were also significantly correlated ($r = 0.20 \pm 0.09$, $p < .001$).

Table 1
Learning, quality, and engagement as a function of grade

	Grade 9		Grade 10		Grade 11		Grade 12	
	M	(CI)	*M*	(CI)	*M*	(CI)	*M*	(CI)
Learning[a]	17.1	±0.70	16.1	±.57	17.1	±.59	18.8	±.63
Males	17.3	±0.89	16.0	±0.72	16.9	±0.78	19.2	±1.01
Females	16.6	±1.06	16.2	±0.70	17.3	±0.81	18.3	±1.10
Quality[b]	14.8	±.45	14.2	±.45	15.4	±.41	16.2	±.48
Males	15.1	±0.67	13.9	±0.53	14.9	±0.59	16.5	±0.78
Females	14.3	±0.83	14.4	±0.51	16.0	±0.61	15.8	±0.86
Engagement[c]	10.1	±.41	9.9	±.35	10.2	±.37	10.8	±.40
Males	10.1	±0.54	9.7	±0.42	10.1	±0.46	11.2	±0.58
Females	9.8	±0.64	10.0	±0.41	10.4	±0.47	10.4	±0.64

CI 95% confidence interval.
[a] Scores ranged form 5 to 25.
[b] Scores ranged form 4 to 20.
[c] Scores ranged from 3 to 15.

3.4. Grade differences

Means scores for student self-assessment of learning, quality, and engagement with respect to learning objects and grade level are presented in Table 1.

A MANOVA was run for student perceptions of how much they learned, the quality of the learning object, and the extent to which they were engaged as a function of grade (Table 2). Significant differences were observed for all three constructs. With respect to learning, a multiple comparisons analysis indicated that grade 12 students had significantly higher scores on the learning and quality scales than grade 9 (Scheffé post hoc analysis, $p < .05$), grade 10 (Scheffé post hoc analysis, $p < .001$), and grade 11 students (Scheffé post hoc analysis, $p < .05$). Regarding learning object quality, grade 12 students had significantly higher scores than grade 9 (Scheffé post hoc analysis, $p < .001$) and 10 students (Scheffé post hoc analysis, $p < .01$). In addition, grade 11 students rate learning objects higher than grade 10 students in terms of learning quality (Scheffé post hoc analysis, $p < .005$). Finally, for engagement grade 12 student score were higher than grade 10 scores Scheffé post hoc analysis, ($p < .05$).

A one-way ANOVA examining student performance as a function of grade level was significant ($p < .001$, Table 3). Grade 12 students ($M = 29.6\%$, $SD = 27.4\%$) performed better than grade 10 ($M = 10.9\%$, $SD = 27.6\%$; Scheffé post hoc analysis, $p < .001$) and grade 9 ($M = 15.9\%$, $SD = 23.6\%$; Scheffé post hoc analysis, $p < .05$) students on their respective learning objects. In terms of change from pre-post test score, grade 12 students appeared to have a 14–19% advantage over grade 9 and 10 students. As well, grade 11 students ($M = 24.3\%$, $SD = 26.1\%$) had higher performance scores than grade 10 students (Scheffé post hoc analysis, $p < .005$).

3.5. Subject taught differences

Means scores for student self-assessment of learning impact, quality, and engagement constructs with respect to subject area taught are presented in Table 4.

A MANOVA was run for student perceptions of how much they learned, the quality of the learning object, and the extent to which they were engaged as a function of subject taught (Table 5). Significant differences were observed for all three constructs. A multiple comparisons analysis revealed that science students rated learning objects higher than math students with respect to perceived learning (Scheffé post hoc analysis, $p < .001$), quality of the learning object (Scheffé post hoc analysis, $p < .001$) and the engagement value (Scheffé post hoc analysis, $p < .001$). In addition, science students rated quality (Scheffé post

Table 2
MANOVA for learning, quality, and engagement as a function of grade

Source	df	SS	MS	F	Post hoc analysis
Learning	3	585.4	195.1	10.5*	G12 > G11, G10, G9
Quality	3	357.2	119.0	11.8*	G12 > G10, G9; G11 > G10
Engagement	3	60.0	20.0	2.9**	G12 > 10

* $p < .001$.
** $p < .05$.

Table 3
Analysis of variance for student performance as a function of grade

Source	Sum of Squares	df	Mean squares	F
Between groups	2.12	3	0.707	14.00*
Within groups	30.74	444	0.069	
Total	32.86	447		

* $p < .001$.

Table 4
Learning, quality, and engagement as a function of subject taught

	Math		Science		Social science	
	M	(SD)	*M*	(SD)	*M*	(SD)
Learning[a]	15.5	±1.5	17.9	±1.0	16.9	±3.7
Quality[b]	13.7	±1.3	15.8	±.9	14.1	±3.1
Engagement[c]	9.4	±0.9	10.7	±0.6	9.6	±4.8

CI 95% confidence intervals.
[a] Scores ranged form 5 to 25.
[b] Scores ranged form 4 to 20.
[c] Scores ranged from 3 to 15.

Table 5
MANOVA for learning, quality, and engagement as a function of subject taught

Source	df	SS	MS	*F*	Post hoc analysis
Learning	2	894.1	447.1	24.6*	Science > Math
Quality	2	707.2	353.6	37.0*	Science > Math, Soc Science
Engagement	2	293.6	146.8	22.4*	Science > Math, Soc Science

* $p < .001$.

Table 6
Analysis of variance for student performance as a function of subject taught

Source	Sum of squares	df	Mean squares	*F*
Between groups	4.00	2	2.000	30.9*
Within groups	28.85	445	0.065	
Total	32.86	447		

* $p < .001$.

hoc analysis, $p < .01$) and engagement (Scheffé post hoc analysis, $p < .05$) significantly higher than social science students.

A one-way ANOVA examining student performance as a function of subject taught was significant ($p < .001$, Table 6). Science students ($M = 25.9\%$, SD = 26.7%) performed better than math ($M = 2.8\%$, SD = 22.4%; Scheffé post hoc analysis, $p < .001$) and social science students ($M = 12.4\%$, SD = 17.4%; Scheffé post hoc analysis, $p < .05$). In addition, social students had higher performance scores than math students (Scheffé post hoc analysis, $p < .05$).

3.6. Computer comfort

Correlations among computer comfort and perceived learning ($r = 0.30 \pm 0.06$, $p < .001$), quality ($r = 0.26 \pm 0.07$, $p < .001$), and engagement ($r = 0.30 \pm 0.06$, $p < .005$) were significant. Student performance, though, was not significantly correlated with computer comfort ($r = 0.01 \pm 0.09$, *ns*). Note that males and females did not differ significantly with respect to computer comfort.

4. Discussion

4.1. Overall variability

Overall, variability among all classrooms was high for all four dependent variables (learning, quality, engagement, and student performance). Above all, this result underlines the need to examine individual differences with respect to the impact of learning objects. Even when students are using the same learning object with the same teacher, some students see little or no benefit while others react very positively. Understanding the sources of variability in learning object use is critical in order to maximize the advantages learning objects have to offer. The purpose of this study, then, was to explore individual differences in the impact of learning objects in secondary school classrooms. A review of the literature suggested that gender, grade, age, subject taught, and computer comfort were good candidates for explaining this variability. Each of these five areas will be discussed in turn.

4.2. Gender differences

Given that gender differences have been fairly small, but persistent over the past 25 years (AAUW, 2000; Barker & Aspray, 2006; Kay, 1992; Sanders, 2006; Whitley, 1997), one might have expected differences to emerge with respect to learning objects. However, no significant differences were observed between males and females for any of the four dependent variables. This finding is consistent with the results reported by Kay and Knaack (2007d) on secondary school students.

One of the reasons that learning objects may be relatively gender neutral with respect to perceived learning and student performance is because they are easy to use. In the past, females have reported being less confident and able to use computers. It is conceivable that the population examined in this study, namely secondary students, may be representative of a new trend citing fewer gender differences (Kay, in press). The fact that males and females did not differ with respect to computer comfort level provides indirect evidence that gender differences at the secondary school level may be disappearing.

4.3. Age differences

The significant correlations observed between age and learning, quality, and engagement ratings were relatively small. The highest correlation between age and perceived learning indicated a shared variance of 1%. On the other hand, the relatively small age range of 12 years may have limited the overall impact. Age may be a factor in learning object use, but appears to have a relatively minimal role in the secondary school environment. It is possible that the overall effect of age would be much greater if learning object use was examined from grade 1 to grade 12.

The correlation between age and student performance was slightly larger. Again, this impact may have been even larger in a more diverse population. The effect of age is partially confounded by the effect of grade level. Older students may be more serious about their studies in general or as previous research suggests, some learning objects may be designed for older, more independent learners (Kay & Knaack, 2007b).

4.4. Grade differences

Differences based on grade level appeared more prominent than age differences. Specifically, grade 12 students had significantly higher scores on all four dependent variables when compared to grade 10 and 9 students. Kay and Knaack (2007d) observed a similar result with secondary school science students. At first, this result might seem somewhat counterintuitive, given that younger students are typically exposed to more technology than their older peers. Furthermore, the culture of high school has not been ingrained in grade 9 and ten students, as much as it has in grade 11 and 12 students. Younger student should be more open to new teaching strategies. However, other grade-specific 'cultural' factors may come into play. For grade 12 students, succeeding is more important, particularly for students wishing to move on to higher education. For grade 9 and 10 students, the urgency of having to perform well may not have emerged yet.

In addition, previous research suggests that older students view a computer as a tool to support learning, whereas younger student see computers as a means of entertainment (Colley, 2003; Colley & Comber, 2003; Comber et al., 1997). Learning objects are typically designed to promote learning, not fun – a goal that would more closely match the needs of the older students. Finally, it is possible, as suggested earlier, that learning objects work better for older students.

4.5. Subject differences

It is somewhat surprising that subject differences emerged in favour of science students over mathematics and social science students. The sample size for the social science population was small, therefore the result may be an anomaly. On the other hand, the availability of social science learning objects was relatively small compared to science and mathematics. Lower scores may simply reflect a poorer quality learning objects.

The differences between science and mathematics are harder to explain, since the number of learning objects available for each subject area was similar. There is no reason to believe that science teachers, on average, selected better learning objects than mathematics teachers. It is possible that science based concepts are more concrete and easier to relate to the real world making them more appealing than more abstract mathematics concepts. This fundamental difference may make science-based learning objects intrinsically more attractive and therefore more successful. It is critical in future research to ask students about their attitude toward a particularly subject area in order to test this hypothesis.

4.6. Computer comfort

Secondary students who were more comfortable with computers tended to rate perceived learning, quality, and engagement of learning objects higher than students who were less comfortable. This result is consistent with previous research on self-efficacy and computer related behaviour. In addition, the lone study looking at secondary school students and learning objects (Kay & Knaack, 2007b) reported a similar finding. The critical point, though, is that computer comfort was not related to student performance. Students with lower computer self-efficacy may not have liked using the learning objects as much as their more confident peers, but performance was largely unaffected. One of the key attributes of learning objects, ease of use, may have tempered the negative impact of computer self-efficacy.

4.7. Implications for education

This study is a first effort to explore individual differences with respect to the effectiveness of learning objects. It would be somewhat premature to offer definitive advice for educators based on the formative analysis offered in the current study. That said, several tentative suggestions may be worth considering. First, gender differences in attitude and performance, for whatever reason, may not be a concern when using learning objects. Second, students in higher grades (e.g., grade 11 and 12) appear to be more receptive to learning objects than students in lower grades (e.g., grade 9 and 10). It is speculated that younger students may need more structure, guidance, and support when using learning objects. Third, learning objects may be more successful in science than in mathematics, although the reason for this is unclear. Perhaps more effort is needed to establish context and engagement with mathematics based learning objects. Finally, computer comfort level may be a problem with respect to attitude toward learning objects, but it does not appear to affect performance. Teachers can be somewhat confident that their less computer savvy students will not be disadvantaged when these tools are being used.

4.8. Future research

Because this study is a formative venture into looking at individual differences in the effectiveness of learning objects, there is clearly room for improvement. The quantitative measures used to assess effectiveness of learning objects in this study were reliable and valid, and one can be reasonably confident that individual differences exist, at some level. That said, it is unclear why these differences are present. More detailed qualitative analysis in the form of interviews, focus groups, or open ended questions are needed to look at:

(a) why grade level differences are observed in the use of learning objects;
(b) why subject differences were observed;

(c) how does attitude toward a specific subject area influence the impact of learning objects;
(d) how effective are learning objects in other subject areas such as English, French, business, and computer science; and
(e) how does ability in a specific subject influence the effectiveness of learning objects;

In addition, it would be worthwhile to look at the impact of instructional strategies on the effectiveness of learning objects. It is conceivable that teachers of higher grades or different subject areas use markedly different teaching methods that influenced the effectiveness of learning objects.

Finally, this study made no attempt to analyse the impact of learning object type. It is possible that individual differences may vary as a function of category of learning objects. For example, younger students may prefer simple question and answer learning objects, whereas older students might require more cognitively challenging tools. Younger students may also prefer more entertaining learning objects with ample multimedia.

4.9. Conclusion

Previous research has not looked at individual differences in the effectiveness of learning objects. This study offers a formative analysis on the impact of gender, age, grade level, subject area, and computer comfort on student attitudes toward learning objects and overall learning performance. No meaningful differences were observed as a result of gender. Age was significantly and positively correlated with student attitudes and performance. Grade 12 students were more positive and performed better than grade 9 and 10 students. Science students rated learning objects higher and performed better than mathematics students. Finally, students who were more comfortable with computers liked learning objects better than their less enthusiastic peers, however, performance was unaffected.

Appendix A

List of learning objects used in the study

Collection	Name of learning object	Web address	**Status**
Anne Frank	Anne Frank the writer	http://www.ushmm.org/museum/exhibit/online/af/htmlsite/	Open
Article 19	Ohm aone	http://www.article19.com/shockwave/oz.htm	Open
Creative Chem	Creative chemistry	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
DNA Int	Gel electrophoresis	http://www.dnai.org/b/index.html	Open
FunBased	Classic chem balancer	http://funbasedlearning.com/chemistry/chemBalancer/	Open
Gizmos	Balancing chemical reactions	http://www.explorelearning.com/	Open
Independent	Congruent triangles	http://argyll.epsb.ca/jreed/math9/strand3/3203.htm	Open
Independent	Triangle centres	http://www.geom.uiuc.edu/~demo5337/Group2/trianglecenters.html	Open
Independent	Life in shadows	http://www.ushmm.org/museum/exhibit/online/hiddenchildren/	Open
Independent	Metals in aqueous solutions	http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/animationsindex.htm	Open

Appendix A (*continued*)

Collection	Name of learning object	Web address	Status
Independent	Ripples of genocide	http://www.ushmm.org/museum/exhibit/online/congojournal/	Open
Learn Alberta	Ammeters and voltmeters	http://www.learnalberta.ca/	Closed
Learn Alberta	Binomial distribution	http://www.learnalberta.ca/content/meda/html/binomialdistributions/index.html?launch=true	Open
Learn Alberta	Multiplying and Dividing cells	http://www.learnalberta.ca/	Closed
Learn Alberta	The exponential function	http://www.learnalberta.ca/content/meda/html/exponentialfunction/index.html?launch=true	Open
NLVM	Algebra balance scales	http://nlvm.usu.edu/en/nav/frames_asid_201_g_4_t_2.html?open=instructions	Open
PBS	Structure of metals	http://www.pbs.org/wgbh/nova/wtc/metal.html	Open
PHET	Energy Skate Park	http://phet.colorado.edu/simulations/energyconservation/energyconservation.jnlp	Open
Waterloo	Waterloo: hydrologic cycle	http://www.region.waterloo.on.ca	Open
Shodor	Maze game	http://www.shodor.org/interactivate/	Open
Bio Project	Online onion root tips	http://www.biology.arizona.edu/Cell_bio/activities/cell_cycle/cell_cycle.html	Open
TLF	Alpha, beta, gamma of rad	http://www.thelearningfederation.edu.au/tlf2/	Closed
TLF	Measuring: similar shapes	http://www.thelearningfederation.edu.au/tlf2/	Closed
TLF	Mobile phone plans	http://www.thelearningfederation.edu.au/tlf2/	Closed
TLF	Reading between the lines	http://education.uoit.ca/lordec/lo/L80/LV5536/	Open
TLF	Squirt: proportional relationships	http://www.thelearningfederation.edu.au/tlf2/	Closed
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	http://education.uoit.ca/EN/main/151820/151827/research_teach_locollection.php	Open
UOIT	Slope of a line	http://education.uoit.ca/EN/main/151820/151827/research_teach_locollection.php	Open
UOIT	Transformation of Parabola	http://education.uoit.ca/EN/main/151820/151827/research_teach_locollection.php	Open
UW Madison	Wild weather	http://cimss.ssec.wisc.edu/satmet/modules/wild_weather/index.html	Open
WISC Online	Periodic table	http://www.wisc-online.com/objects/index_tj.asp?objid=SCI202	Open
Zona land	Equation of a line	http://id.mind.net/~zona/mmts/functionInstitute/linearFunctions/lsif.html	Open

Appendix B

Learning object evaluation survey – students

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

Appendix C

Overall variability for learning, quality, engagement and student performance

n	Learn[a]			Quality[b]			Engage[c]			% Change from pre- to post-test		
	Min	Max	SD	Min	Max	SD	Min	Max	SD	Min (%)	Max (%)	SD (%)
17	12	25	3.2	9	20	2.8	7	15	2.3	17	83	20
20	5	22	5.1	4	19	3.2	3	12	3.0	−33	83	30
18	15	25	3.0	14	20	1.6	8	15	2.0	−8	33	15
13	5	25	6.0	8	20	3.2	3	15	3.6	NR	NR	NR
11	12	25	4.3	12	20	3.4	7	15	2.8	NR	NR	NR
11	8	25	4.9	10	20	2.8	4	15	3.2	NR	NR	NR
18	9	24	3.4	6	20	3.3	5	14	2.2	−13	75	23
22	9	19	3.1	10	18	2.2	4	13	2.2	−25	17	11
10	15	23	2.8	14	20	2.3	8	14	1.8	−17	67	32
15	14	24	2.9	12	20	2.0	7	13	1.7	30	90	17
15	5	25	5.5	10	20	3.6	4	14	2.9	NR	NR	NR
13	8	25	4.0	13	20	2.1	3	15	2.9	25	83	16
15	15	24	2.7	10	20	3.0	4	15	3.1	25	71	16
14	9	25	4.1	12	18	1.7	4	15	2.5	−15	35	16
9	5	22	5.1	9	16	2.1	3	13	3.0	−25	31	19

Appendix C (*continued*)

n	Learn[a]			Quality[b]			Engage[c]			% Change from pre- to post-test		
	Min	Max	SD	Min	Max	SD	Min	Max	SD	Min (%)	Max (%)	SD (%)
21	5	21	4.5	4	16	3.8	3	12	2.6	−50	50	26
16	5	22	4.5	4	20	4.3	3	12	2.6	−50	75	32
19	5	20	4.2	9	18	2.3	4	12	2.6	−14	21	12
13	7	20	4.1	9	18	2.6	4	12	2.2	−29	43	21
14	6	20	5.2	5	16	3.6	3	11	2.3	−50	20	25
16	10	25	3.5	11	20	2.6	6	15	2.4	0	60	19
11	12	25	3.3	12	19	2.1	9	15	1.8	0	80	26
4	13	20	3.5	10	19	4.0	9	11	0.9	−17	17	15
10	9	22	4.3	4	19	4.9	5	13	2.6	−8	0	5
13	15	25	3.0	15	20	1.7	9	15	1.9	10	100	24
7	11	20	3.1	13	20	2.9	8	14	1.9	−25	25	19
17	5	24	5.6	4	20	4.7	3	14	3.2	−20	40	16
10	12	25	3.8	8	20	3.8	3	15	3.2	NR	NR	NR
9	10	23	5.1	12	20	2.7	7	13	2.5	NR	NR	NR
11	8	21	3.7	4	17	4.1	5	12	2.4	NR	NR	NR
16	12	22	2.8	9	18	2.5	6	13	1.9	−20	45	16
10	12	23	4.2	14	19	1.8	6	14	2.2	0	50	18
15	10	21	2.9	12	19	2.2	6	15	2.0	NR	NR	NR
12	10	23	4.0	8	20	4.0	6	14	2.6	NR	NR	NR
19	5	24	5.2	7	17	3.2	3	13	2.8	NR	NR	NR
10	10	23	3.9	12	20	2.8	4	14	2.8	NR	NR	NR
7	9	20	3.8	10	17	2.5	7	15	2.4	NR	NR	NR
22	9	25	3.7	10	19	2.8	6	15	2.1	−10	90	26
24	14	25	3.3	11	20	2.4	8	13	1.6	−25	44	18
22	14	25	3.1	12	20	1.9	6	15	2.3	−7	43	16
12	6	20	4.4	11	19	2.8	7	14	1.8	−14	36	13
19	7	23	3.9	12	19	2.1	7	15	2.0	−17	71	25
22	8	25	4.3	12	20	2.6	6	15	2.3	−11	28	8
4	12	20	4.0	13	16	1.5	8	10	1.0	−50	63	53
21	9	24	3.8	13	19	1.9	3	13	2.9	NR	NR	NR
15	5	22	4.9	8	20	3.4	3	14	2.9	−42	67	28
15	5	22	4.3	4	20	3.9	3	12	2.7	−29	36	20
13	5	22	11	18	2.2	3	15	2.8	−60	−60	47	30
14	16	24	2.4	12	20	2.0	8	14	1.6	−60	63	34
29	6	22	3.6	7	20	2.7	7	15	1.9	NR	NR	NR
23	5	25	3.9	11	20	2.6	6	15	2.4	−20	70	22
22	10	25	3.8	9	20	3.1	5	15	2.3	−40	70	31
17	5	23	4.3	4	20	3.2	3	15	2.6	−60	100	28

NR Not reported.
[a] Maximum possible range of scale was 5–25.
[b] Maximum possible range of scale was 4–20.
[c] Maximum possible range of scale was 3–15.

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