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The impact of group setting and visual representations on secondary school students' learning outcomes

Abstract

Research on the impact, effectiveness, and usefulness of learning objects is scarce, particularly in secondary education. The goal of this study was twofold. First, we examined the impact of the extent to which visual representations are presented in learning objects on learning outcomes. Simultaneously, we studied the impact of an individual versus a collaborative setting on learning outcomes. The study took place in a biology course, 511 secondary school students were involved.

Keywords: secondary school, learning object, science education

Theoretical framework

The term “learning objects” is popular and often used, but it is not always clearly defined what a learning object actually is. Presumably the most cited definition of learning objects comes from the Learning Technology Standards Committee (also known as IEEE, 2000, 2005). This Committee defines a learning object as “any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning”. Wiley (2002) adds that although several groups have narrowed and refined this definition, they always respected the strictest sense of it as foreseen by the IEEE. In his dissertation’s review on the existing literature on definitions of learning objects, Kim (2009) concluded that most of the definitions include terms like “learning”, “instructional”, “pedagogical” or “educational”. In this paper, we prefer the more pedagogically based definition by Kay and Knaack (2007b), who defined learning objects as “interactive web-based tools that support the learning of specific concepts by enhancing, amplifying, and/or guiding the cognitive processes of learners” (p. 6).

The design, development, re-use, accessibility, and use of learning objects has been extensively examined the last decade (Kay & Knaack, 2007b). However, in their review of 58 articles, Kay and Knaack found only two papers that examined the impact of learning objects on learning. This was also confirmed by Nurmi and Jaakkola (2005) who argued that there was limited empirical evidence in research papers concerning the impact, effectiveness, and usefulness of learning objects.

A lot of research has been done within the Cognitive Theory of Multimedia Learning (CTML) posited by Mayer (2001), representing a clear framework to direct instructional design of both printed and interactive multimedia materials and resulting in the definition of practical principles for multimedia learning material. De Westelinck, Valcke, De Craene, and Kirschner (2005) warned that although CTML-research has

provided proof that using these principles for developing learning materials resulted in higher performance on knowledge- and application tests, other CTML-related research presented inconsistent results about the impact on student performance.

Cochrane (2005) found that research usually applies to traditional instructional design, but found relatively little research specific to design principles for learning objects. Dalziel (2003) argued that e-learning usually has “a well-developed approach to the creation and sequencing of content-based, single learner, self-paced learning objects”, but added that “there is little understanding of how to create sequences of learning activities which involve groups of learners interacting within a structured set of collaborative environments” (p. 593). A complete model identifying the processes involved within collaborative knowledge building, based on activity theory (Engeström, 1987) and the role of reflection (Lin, Hmelo, Kinzer & Secules, 1999), was developed by Singh, Hawkins and Whymark (2007). Rosen and Rimor (2009) argued that the relationship between the individual and the group components in the process of collaborative knowledge building deserves further investigation.

Purpose

Given this lack of empirical research focusing on how learning objects should be built, presented, and processed and the impact of this design on students’ performance, we will concentrate in this study on the impact of learning objects on learning outcomes of secondary school students, who are an understudied group (Kay & Knaack, 2008). We will focus on four conditions, namely on the extent to which visual representations are presented in learning objects (reduced versus amplified) and secondly on the significance of group setting in the classroom (individual versus collaborative).

Method

Design

This study is quasi-experimental in nature, since we chose to conduct it in an authentic setting, namely real-life classrooms. Due to this decision, complete classes were assigned to the four different conditions. This approach is not fully randomized. However, a higher level of ecological validity can not be reached, since it is important to take into account the reality that a large number of secondary schools can not participate as they don’t have sufficient computer labs.

Learning objects

Learning objects in this study were made with eXe learning. The eXe project is a freely available open source authoring tool (Exe, 2011). Resources authored in eXe can be exported as a website or exchanged via any SCORM (Sharable Content Object Reference Model)-conformant Learning Management System (Advanced Distributed Learning Initiative, 2011).

Sample

Nine teachers (3 males, 6 females) from 7 different secondary schools participated. As most of the instructors had several groups following the same course, we invited all of their classes to participate in this study. All lessons took place in a computer lab.

The student sample consisted of 511 students (257 males, 254 females), nonetheless only 392 students were taken into account as they completed the full course. They were all second grade secondary school students following a compulsory biology course. 74,4% of the students were 15 years old and 20,4% were 16 years old.

Procedure

Within the biology course, the bacteria topic was chosen. In order to simulate a real-world setting, two biology teachers created learning materials. Subsequently, these materials were reviewed and modified by 18 pre-service teachers majoring in biology under the supervision of their lecturer.

Within the second grade biology curriculum, the bacteria topic typically consists of 4 lessons. A series of learning objects covering the full bacteria subject was created, using eXe learning and exported as a SCORM object. This SCORM object could be imported into the teacher's Learning Management System. As mentioned earlier, the difference between the two SCORM objects was the extent to which visual representations were presented. SCORM object 1 was a combination of pictures, text, schema and web-based exercises. Version 2 was an extended version of learning object 1, containing more pictures, schema and web-based exercises (see Figure 1 for a screenshot example).

Figure 1
Screenshot example of a learning object

Deze cursus | Leerpap

- Bacterien**
- Bouwen | Organiseren | Weergeven
- Bacterien ✓
- Inleiding ✓
- Wat zijn bacteriën? ✓
- levende wezens ✓
- eigenschappen ✓
- de delen van een bacteriecel ✓**
- toets je kennis
- Indeling van verschillende bacteriën
- indeling naar vorm
- gramkleuring
- toets je kennis
- Waar leven de bacteriën?
- proef
- overleven
- toets je kennis

18%



de delen van een bacteriecel

Schematische voorstelling van een bacterie en de verschillende delen ervan.

Celmembraan
Het celmembraan is een dun vliesje dat omheen het cytoplasma ligt.

Celwand
De celwand is een wand die om het celmembraan ligt en bepaalt de vorm en de stevigheid van de cel. Zonder celwand zou een bacteriecel openbarsten door de druk van het cytoplasma op het celmembraan. Naast die van bacteriën hebben ook de cellen van protisten, zwammen en planten een celwand. Dierlijke cellen hebben geen celwand.

Veel soorten bacteriën vormen aan de buitenzijde van de celwand een **slijm laag** omgeven door een **eiwitkapsel** dat dient als een bescherm laag.

Cytoplasma
Het grootste deel van de cel bestaat uit cytoplasma dat voor het grootste deel bestaat uit water.

Ribosomen
Ribosomen zijn structuren die je in alle cellen terugvindt. ze zijn heel belangrijk zijn voor de opbouw van eiwitten.

Chromosomen
Chromosomen zijn de dragers van erfelijke informatie (DNA). Bacteriën bezitten een ringvormig chromosoom.

Flagellen

Teachers were briefed on how to use the material in their classes. In addition to the learning objects all participating teachers received a comprehensive lesson plan. Other topics discussed included amongst other the proposed time schedule and technical information concerning learning objects within the Learning Management System.

Data sources

Students were offered three knowledge tests on 3 different moments: a pre-test (before starting the bacteria course), a post-test (immediately after completing the course) and a retention-test (a month after completion). Each student was scored on a scale from 0 to 20. The format of these tests was similar at all points in time. The tests consisted out of 20 multiple choice true/false questions, on which guessing was allowed. Teachers were asked not to announce any of the tests.

Results

Data analysis

A series of analyses were run to research the effects of our conditions on learning outcomes. These include:

1. pair wise comparisons of knowledge tests;
2. a 2x2 factorial design to test the impact of the four conditions of learning objects on learning outcomes.

Knowledge tests

Table 1 shows the descriptives for the 3 different knowledge tests. Only 392 students of the total sample completed all tests. The means clearly show an increase in scores during the testing period.

Table 1
Descriptives of knowledge tests

	N	Mean	Standard deviation
Pre-test	392	13.33	2.45
Post-test	392	14.53	2.28
Retention-test	392	14.61	2.54

A repeated-measures ANOVA analysis was carried out comparing the knowledge tests. Using the Greenhouse-Geisser correction, results showed that there was a significant overall difference between conditions ($F(2,778) = 46.82, p < 0.001$) and an overall effect size of 0.11 (Eta squared). Pair wise comparisons show a significant difference between the pre-test and the post-test (mean difference 1.20) and the pre-test and the retention-test (mean difference 1.30), but a negligible and non-significant difference between the post-test and the retention-test (mean difference 0.10).

Table 2
Pair wise comparisons

(I) PU	(J) PU	Mean difference (I-J)	Std.error	Sig.	95% Confidence interval for difference ^a	
					Lower bound	Upper bound
1	2	-1.202*	0.145	0.000	-1.551	-0.852
	3	-1.304 *	0.150	0.000	-1.663	-0.944
2	1	1.202*	0.145	0.000	0.852	1.551
	3	-0.102	0.154	1.000	-0.473	0.269
3	1	1.304 *	0.150	0.000	0.944	1.663
	2	0.102	0.154	1.000	-0.269	0.473

Note: *The mean difference is significant at the 0.05 level. ^a Adjustment for multiple comparisons: Bonferroni.

2 x 2 factorial design

The learning outcomes were calculated as the difference between the post-test and the pre-test. They were analyzed using a factorial analysis of variance with two between-participant factors. Learning outcomes will serve as dependent variable; the extent to which visual representations are presented in learning objects (reduced versus amplified) and group setting in the classroom (individual versus collaborative) are independent variables.

As can be observed from the descriptive statistics in Table 3, the number of participants differs between the conditions. To get a better view on the learning outcomes, we will be using a line graph.

Table 3
Descriptive statistics dependent variable

Group setting	Visual representations	
	Reduced	Amplified
	M (SD)	M (SD)
Individual	1.11 (3.48)	2.47 (2.70)
Collaborative	1.06 (2.57)	.11 (2.81)

Note. *M* = Mean; *SD* = Standard deviation.

Figure 2 Line graph illustrating the interaction between the extent to which visual representations are presented in learning objects and group setting on learning outcomes.

Estimated Marginal Means of Learning outcomes (post-pre)

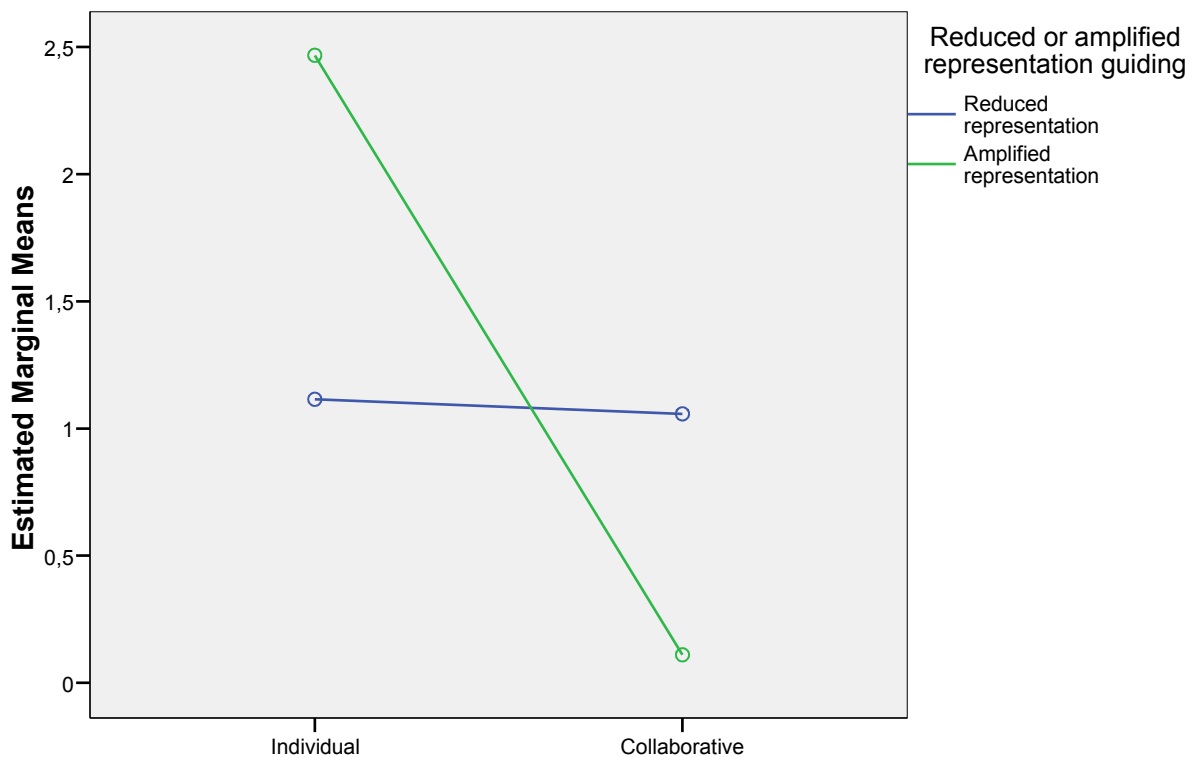


Figure 2 shows that the learning outcomes of students who were offered a reduced representation was equal in the individual ($M = 1.11$) and the collaborative group setting ($M = 1.06$). On the other hand, students who were offered an amplified representation performed much better in the individual setting ($M = 2.47$) than in the collaborative setting ($M = 0.11$). When focusing on the main effects separately, the difference between a reduced representation ($M = 1.08$) and an amplified

representation ($M = 1.58$) is rather small but not significant. The difference between students working alone in front of the computer ($M = 1.75$) or in group ($M = 0.76$) is more distinct and significant.

Table 4
A2x2 factorial design

Source	Sum of Squares	df	Mean square	F	Sig.	Partial Eta Squared
Corrected Model	249.076 (a)	3	83.025	9.657	.001	.062
Intercept	567.246	1	567.246	65.978	.001	.131
Group setting	146.766	1	146.766	17.071	.001	.038
Representation	4.127	1	4.127	.480	.489	.001
Group setting * Representation	133.155	1	133.155	15.488	.001	.034
Error	3765.695	43	8.597			
Total	4737.000	44				
Corrected Total	4014.771	44				

Note. (a) R Squared = .062 (Adjusted R Squared = .056)

The analysis revealed that the main effect due to group setting was significant ($F(146,8.6) = 17.07, p = .001$, partial $\eta^2 = 0.038$, Cohen's $d: 0.32$, effect size $r = 0.160$), whereas the main effect of representation guiding (reduced or amplified) was not significant ($F(4,8.6) = 0.48, p = .489$, partial $\eta^2 = 0.001$, Cohen's $d: -0.17$, effect size $r = -0.083$). The interaction between the main effects was found to be significant ($F(133,8.6) = 15.49, p = .001$, partial $\eta^2 = 0.034$).

Scientific significance

The purpose of this research was to explore the impact of 4 real class situations on learning outcomes, when secondary school students followed a biology course of 4 lessons. This study was quasi-experimental in nature, with a large population.

Results showed that the learning outcomes of students who were offered learning objects with reduced representations were almost equal in the individual and the collaborative group setting. Students who were offered an amplified representation performed much better in the individual setting than in the collaborative setting. These outcomes suggest that the fact that these students were working together affected their learning in a negative way. Although further research is required, the results in this study are important for educators, designers, and researchers.

At least three key areas should be addressed in future research. First, it is not completely clear what the role of the teacher was in our study. Qualitative data should

support and clarify the current results. Second, the group composition of the students should be examined and be more detailed (e.g. same-sex vs. mixed-sex groups). Third, a detailed description of student behavior at the computer could provide insights about the way they handle the learning objects. Given the learning outcomes in the collaborative setting, it would be interesting to learn how students work together. Students could for instance be video-taped, computer actions logged and computer screens captured.

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