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TOOL USE IN COMPUTER-BASED LEARNING ENVIRONMENTS: ADVICE AND COGNITIVE LOAD

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Abstract

Providing learners with control over tools in interactive learning environments (ILEs) is suggested to be effective in raising learners' motivation and learning outcomes. However, research indicates that learners do not always adequately use the tools they are given control over. In an attempt to tackle this issue, scholars suggested providing learners with advice in order to support the tool selection process. This study focuses on the effects of tool-related advice on perceived cognitive load, learning gains and motivation. In an ILE on gamification, participants were randomly assigned to two conditions: learner control over tools and learner control over tools with additional advice. Their main goal was to create a mindmap on gamification with the availability of seven tools. Results indicate that advice does not have an effect on experienced cognitive load, motivation and learning gains. These results are related to the content of the task and tool-related perceptions.

Introduction

Many theorists point out the steep rise of computers in education (Aleven et al., 2003). With this rise of technology in education, came the birth of Interactive Learning Environments (ILEs). Aleven and his colleagues (2003) define ILEs as "computer based instructional systems that offer a task environment and provide support to help novices learn skills or concepts involved in that task" (p.279). ILEs have two main features. First, ILEs use technology to support the learning process by providing tools and resources that enhance the construction of knowledge. Second, ILEs have the potential to shift control towards the learner (Scheiter & Gerjets, 2007).

Although providing learner control (LC) over these tools is thought to be beneficial for several reasons, research reveals mixed results (Lawless & Brown, 1997). Next to this, a main concern is that even though control over tools is often provided, tool use is often far from optimal (Aleven et al., 2003). Educational scientists have attempted to tackle this problem by providing advice for a learner on which tools to use. However, the added value of advice on either motivation or learning has not been clearly demonstrated yet (Vandewaetere, 2012).

The aim of this paper is to go deeper into the background of these mixed results, by bringing a cognitive load perspective into the equation. First, the notion of self-controlled tool use will be elaborated on. Second, the relationship between advice and tool use will be untangled. Further, the findings on advice and tool use will be translated into a cognitive load perspective, taking learners' perceptions into account.

Self-controlled tool use

Tools can be described as features or resources in an ILE which can help a learner to enhance their knowledge construction (Clarebout & Elen, 2006). This definition defines the concept of 'tool' broadly and suggests that tools can be divided in several categories. In order to make different types of tools more insightful, they created a classification system. The different types of tools are depicted in Table 1, accompanied with an example.

In this paper, the focus is on control over these tools. Several researchers have pointed out that tool use in ILEs often is suboptimal or even non-existing (Aleven et al., 2003; Elen & Clarebout, 2007). For learners to optimally use the tools they are provided control over, three conditions must be met (Perkins, 1985; Winne 2006).

First of all, these tools have to be perceived as functional by learners for the learning process at a given time in the ILE. While the tools have the potential to help structure the student's knowledge construction, the student might not realize this and hence does not perceive the tools as functional. Second, learners have to be motivated to spend time and effort in using the tools. In this case, tools might not be used because this will only result in having to spend more time to the experiment. Third, learners have to be instructionally knowledgeable. To tackle the issue of suboptimal tool use, researchers have brought a facilitator into the picture: advice.

Table 1: Types of Tools According to Clarebout and Elen (2006)

Tool type	**Tool goal**	**Example**
Information tools	Provide learners with information	Theory document
Cognitive tools	Assist learners in processing stimuli	Table of content
Knowledge modelling tools	Help learners to reflect on the learning process	Summary
Performance support tools	Assist learners in completing secondary tasks	Calculator
Information gathering tools	Help learners in searching for information	Google.com
Elaboration tools	Give access to additional exercises and practice	simulation tool
Conversation and collaboration tools	Provide learners with the opportunity to share knowledge	e-mail; chat

Advice and advice on tool use

To overcome the issue that learners do not adequately use the control they are given in ILEs, theorists have suggested bringing advisement into the picture (Kirschner et al., 2006). Advice

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can provide learners with more insights about the what-and-how of tools and can calibrate the learner's perceptions to the tool functionalities. The above mentioned frameworks of Perkins (1985) and Winne (2006) provide more insights to this reasoning. First of all, as an ILE advice is given to use certain tools, learners become aware that certain tools can be helpful for learning (condition 1). Gaining knowledge in the characteristics of the tools might lead to the fact that learners can more adequately see the benefits of a using a certain tool. Giving advice might thus enhance the perceived functionality of a certain tool. This in turn might lead to a higher motivation to spend time and effort in using the tools (condition 2). Finally, as learners gain knowledge about the intended use of tools, they might become more instructionally knowledgeable.

However, recent research reports mixed results on the effect of advice on self-controlled tool use (Clarebout & Elen, 2008). In a study conducted by Gräsel, Fischer and Mandl (2001), medical students had to solve a case on anaemia and could use a glossary tool, a data base tool and a tool that provided diagnostic help. The experimental group received additional advice by previously watching an experienced practitioner solve the case. The type of advice learners received in this study is identified by the authors as expert modelling. Analysis of the think aloud protocols revealed that advice on the tools let to a higher frequency of tool use. However, learners were not always able to adequately use or integrate the additional information in the problem solving process (Gräsel et al., 2001). It can be summarized that although theory predicts a beneficial role of advice, research does not show clear results. The next section might give us an insight into a possible explanation.

Advice, LC and Cognitive Load Theory

Providing control to learners in an ILE can impose an additional cognitive load on the working memory of the learners (Niederhauser et al., 2000) and can hamper learning (Scheiter & Gerjets, 2007). Learners' working memory has a limited capacity (Miller, 1956) and a vast body of research has shown that working memory capacity (WMC) differs between individuals (for a recent review see Unsworth & Engle, 2007). Recent studies have connected WMC with LC in ILEs. For example, in a study conducted by Vandewaetere and Clarebout (2011) university students took part in an online English course on grammar. The students were randomly assigned to a condition with no LC, LC as such and LC with instruction. The researchers found that WMC, as measured through the group administrable operation span task (GOSPAN; De Neys et al., 2002) was positively related to learning outcomes. They found this pattern regardless whether additional instruction was provided or not. This might indicate that learners with a higher WMC have more additional "free space" in their WM resulting in more efficient processing of information which in turn leads to higher learning outcomes.

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This study

This study focuses on the effect that additional advice on tool use has on learning outcomes, post-experimental motivation and experienced cognitive load. As additional advice might synchronize the perceptions' of learners about when to use a tool, the right information becomes accessible at the right time. Amongst others, Elaboration Theory of Instructions (Reigeluth & Stein, 1983) and the 4C/ID model (van Merriënboer et al., 2002) predict better learning and motivation in these circumstances. Consequently, it is hypothesized that additional advice enhances learning outcomes. In addition, as advice can calibrates learner's perceptions, cognitive load might be reduced. Therefore, it is hypothesized that advice is associated with a lower perceived cognitive load.

Method

Participants

Eighty-nine students took part in this study, they received extra credit in a course from the first bachelor year Educational Sciences. The age range was between 18 and 23 years, with M = 19 and SD = 1.12. Of the participants, 97% (n = 86) were female. One case was removed from the analysis due to missing data.

Procedure and Materials

Before the experiment took place, prior knowledge on gamification (5 open questions and 10 multiple choice questions), and learners' motivation (MSLQ); were measured through on-line questionnaires. Participants also filled out questions regarding their experience with the techniques of mindmapping. Afterwards, participants were invited to a computer classroom where they completed the course on gamification.

Before starting the actual course, oral instructions were given and WMC was measured (GOSPAN). The course was offered via Moodle, an online platform for e-learning. During the course, the main task was to create a paper-and-pencil mindmap on the topic of gamification. To fulfil this goal, participants had full control over seven different tools and a time limit of two hours. The available tools were a figure which depicted a mindmap with instructions on how to make a mindmap, a 25-minute video which contained a presentation on gamification, a PDF file which provided hints on gamification, a second PDF file which contained applications of gamification, a third PDF file with some principles on gamification in education, a fourth PDF file containing an overview of the advantages of serious games and finally the online search engine Google. All tools were offered in the ILE by hyperlinks. The two conditions in this design are: control over tools (C; n=48) and control over tools with additional advice (CA; n=41). In both conditions, participants received a sheet with explanation on the seven tools they could use. In the CA condition, participants received additional instructions on how and when to use specific tools.

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After creating the mindmap, participants were asked to complete the post-experimental questionnaires. These comprised a motivation questionnaire (IMI), a questionnaire on perceived cognitive load (NASA Task Load Index) and a test on gamification (identical as to the pre-test). Finally, questions about the mental effort required using certain tools, and the perceived functionality of tools had to be answered.

Tracking and logging data on learning behaviour (e.g. proportion of correct answers on knowledge tests, frequency of tool use) were also collected.

Results

Learning outcomes

To determine learning outcomes, two measures were used. A first measure was the score on the post-test. A second measure that was used to assess learning outcomes was the quality of the mindmaps (several aspects rated by three raters; interrater correlations between .67 and .77).

Since both measures (i.c., quality of the mindmaps and the score on the post-test) were not correlated, it was decided to request two separate ANCOVA's. In the first ANCOVA, condition was entered as factor, pre-experimental knowledge as a covariate and post-test score as the dependent variable. In the second ANCOVA, condition was also entered as a factor, but quality of the mindmaps was entered as the dependent variable, controlling for experience with mindmaps. Results show that, after controlling for pre-experimental knowledge and experience with mindmaps, there is no significant difference in learning outcomes between the conditions (post-test score, $F(1,86)=.02$, *ns*; quality of mindmap, $F(1,85)=.06$, *ns*).

Motivation

An ANOVA was requested with post-experimental motivation as dependent variable and condition as factor. The results showed that there was no significant difference between the C and the CA condition regarding post-experimental motivation ($F(1, 86)=.01$, *ns*).

Perceived cognitive load

A one-way ANCOVA was requested with C and CA as levels. WMC was entered as a covariate. Against expectations, there was no difference in experienced cognitive load between the conditions ($F(1, 86)=.00$, *ns*), after controlling for WMC.

Tool use behaviour

A total score per participant was calculated by adding up the use frequencies of the different tools. This score was entered in an ANOVA with condition as factor. The analysis revealed that there was no significant difference in tool use behaviour between the C and CA condition ($F(1, 84)=.85$, *ns*).

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Advice and tool related perceptions

To test whether the mental effort for each tool differed over the conditions, seven one-way ANOVAs were conducted. The results are listed in Table 2. For all tools, there was no significant difference between the two conditions.

Table 2: ANOVAs for mental effort ratings, based on the mental effort rating scale (Paas, 1992) (1=very, very low effort; 9=very, very high effort), for students who have used the specific tool.

Tool	**Condition Control**	**Condition Control with Advice**	**Anova result**
Mindmap (figure)	3.27	3.33	F(1,85)=.02, ns
Gamification (video)	5.21	5.45	F(1,81)=.74, ns
Hints (pdf)	4.23	4.03	F(1,85)=.40, ns
Applications (pdf)	4.00	3.82	F(1,82)=.29, ns
Principles (pdf)	4.47	4.13	F(1,85)=.27, ns
Advantages serious games (pdf)	4.30	4.13	F(1,83)=.24, ns
Google.com	2.91	3.00	F(1,50)=.03, ns*

*Note. Degrees of freedom associated with F differ per ANOVA as participants could indicate that they did not use a tool.

To test whether the perceived usefulness of tools and the perceived difficulty in using these tools differed amongst conditions, two times seven ANOVA's were requested. There was no significant difference for the tools in perceived difficulty between conditions. However, there was a significant difference between conditions in perceived usefulness for two tools. The gamification video tool was perceived as less useful in the CA condition ($F(1, 80)=5.97$, $p<.05$) and the pdf containing advantages of serious games was perceived as less useful in the C condition ($F(1, 79)=9.37$, $p<.01$)

Advice and tool use behaviour

Tool use behaviour was also registered during the learning phase. A total score per participant was calculated by adding up the use frequencies of the different tools. This score was entered in an ANOVA with condition as factor. The analysis revealed that there was no significant difference in tool use behaviour between the C and CA condition ($F(1, 84)=.85$, *ns*).

Discussion

The goal of this study was to investigate the effect of additional advice on tools that were under full control of learners on perceived cognitive load, post-experimental motivation and learning outcomes. In order examine this effect, two groups were compared. The first group had full control over the tools they could use to complete the task at the end of the ILE: creating a mindmap on the topic of gamification. The second group also had full control over tools, but received additional advice on which tools to use and when they could be used best.

It was hypothesized that additional advice on tool use would enhance motivation and learning outcomes. Second, it was expected that advice lowered would lower the cognitive load of the task. In this study, providing additional advice over tool selection was not related to higher motivation and learning outcomes and to lower experienced cognitive load. Although these results might seem unsatisfactory, research on advice and self-controlled tool use benefits from these results. Hence, some elaboration is indispensable.

When inspecting the results of tool use behaviour and mental effort ratings per tool, we neither see an effect of advice. Despite that these findings do not allow to draw conclusions on the cognitive load this control over tools might generate, mental effort ratings also suggest that advice does not alter the mental effort that learners experience in using the tool. However, these mental effort ratings only give an idea of the mental effort of the use of different tools per se and not of the mental effort participants experienced in selecting or deciding what tool to use.

A possible clue for an explanation of why advice might not have lowered the perceived cognitive load of the task or the mental effort participants experienced in using a tool might be found in the qualitative analysis of the question why participants did not use certain tools. Some participants indicate that they first browsed through all tools to get an idea of all the information available and only after this they began drawing the mindmap. Also, inspection of the handed-in instruction bundles revealed that some participants took notes and created small schemes before they started completing the mindmap. These cues might indicate that the participants used their own tools and strategies to lower the cognitive load, as by using these tools and techniques it might become possible for the learner to act upon the limits of his or her own working memory. With respect to the experienced cognitive load of the task, it is possible that learners already equalled out a part of the experienced cognitive load, as it was reduced by their own scaffolds or self-regulation strategies.

Limitations and suggestions for future research

A first drawback of this study is that there was no condition included without LC. As research on the effect of LC over tools on motivation, learning and cognitive load stays inconclusive, the inclusion of a no LC condition would have allowed comparisons between the LC and no LC condition.

A second limitation of this study is the fact that learners' perceptions were measured after the experimental phase. This does not allow drawing conclusions about how these perceptions might mediate the relationship between advice, tool use and cognitive load. For future research it might be interesting to measure tool perceptions before or during the experimental phase.

Finally, a conceptual drawback should be mentioned. As tools are described as resources that can help a learner to construct knowledge, the reader of this paper could have noticed that learners did not have a full choice. As the learning content of the ILE was scattered across

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tools, learners actually had control over the pace of learning rather than the tools they could use. In fact, without the use of at least one tool, the learning effect of the ILE would be undefined, as there would have not been an interaction between the learner and the content.

In this study, providing additional advice over tool selection was not related to higher motivation and learning outcomes and to a decrease in experienced cognitive load. The results can be partly explained by the learners not following the advice. Learners reported that they had own strategies to deal with the tools (for example, going through all tools before starting the task) and that advice had not altered those. The results of this study suggest that advice for optimizing self-regulated learning strategies might be more beneficial than advice over tool-use.

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