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Résumé de l'article

Embedding support devices in educational computer games has been asserted to positively affect learning outcomes. However, there is only limited direct empirical evidence on which design variations of support provision influence learning. In order to better understand the impact of support design on novices' learning, the current study investigates how support devices and their type of provision (intrinsic vs. extrinsic) determine games' effectiveness on learning outcomes. This effectiveness is also related to how the design-type of provision influences learners' virtual presence and cognitive load. Compared to an educational adventure game without additional support, the results indicate that the game equipped with support devices enhances learning outcomes, although no differences in cognitive load were found. A variation in the design of provision shows no effect. In order to gain a more thorough understanding of support devices and their design for games, additional learner characteristics (e.g., interest) should be considered in future research.

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Learning in Educational Computer Games for Novices: The Impact of Support Provision Types on Virtual Presence, Cognitive Load, and Learning Outcomes


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Abstract

Embedding support devices in educational computer games has been asserted to positively affect learning outcomes. However, there is only limited direct empirical evidence on which design variations of support provision influence learning. In order to better understand the impact of support design on novices' learning, the current study investigates how support devices and their type of provision (intrinsic vs. extrinsic) determine games' effectiveness on learning outcomes. This effectiveness is also related to how the design-type of provision influences learners' virtual presence and cognitive load. Compared to an educational adventure game without additional support, the results indicate that the game equipped with support devices enhances learning outcomes, although no differences in cognitive load were found. A variation in the design of provision shows no effect. In order to gain a more thorough understanding of support devices and their design for games, additional learner characteristics (e.g., interest) should be considered in future research.

Keywords: Open learning; e-learning; educational computer games

Introduction

Instructional approaches based on discovery (Bruner, 1961), experiential (Kolb, 1983), or problem-based learning (Barrows & Tamblyn, 1980) as well as constructivist ideas (Jonassen, 1991) stress the importance of learning environments such as educational computer games. They are seen as opportunities to enhance learning and motivation by offering learners open-ended, autonomous learning. As they permit learners to discover or construct learning information themselves, theorists consider them to be a promising alternative to the presently more common approach of presenting learners with information for example by listening to a teacher (Kirschner, Sweller, & Clark, 2006). Although the beneficial effects of autonomous learning in educational games are supported from a theoretical perspective, empirical research shows both beneficial and detrimental effects on learning outcomes (e.g., Beale et al., 2007; Dede et al., 1997, 2005; Parchman et al., 2000; Wong et al., 2007). While some learners benefit from learning in educational computer games, for other learners, especially those with little prior knowledge, educational games have proven no more effective than traditional media (for an overview on games' learning effectiveness see Schrader, 2010; Schrader & Bastiaens, in press). According to Kirschner et al. (2006), one of the potential threats not only of educational computer games but of all discovery-based, problem-based, or experiential learning environments is that they make heavy demands on learners' working memory capacity by requiring unnecessary cognitive load that exceeds the limitation of working memory. In this case, learning will be inhibited (Sweller, 1993). Following the line of cognitive load theory (Chandler & Sweller, 1991; Sweller, 1994, 1999), the total cognitive load imposed on working memory during learning is additively composed of three load types: intrinsic cognitive load, extraneous cognitive load, and germane cognitive load. Intrinsic cognitive load depends on the complexity of the given task in relation to learners' level of expertise. Extraneous cognitive load depends on the instructional design of learning material; whereas, germane cognitive load results from learners' engagement in the learning activity. During learning with games, an example of intrinsic and extraneous factors that overload learners' processing resources is the amount and complexity of information that needs to be processed, combined with simultaneous actions of cognitive and motor activities (Kalyuga & Plass, 2009; Kerres, Bormann, & Vervenne, 2009; Lim, Nonis, & Hedberg, 2006; Whitton, 2010). Learners have to give high attention to how to manipulate the game and control experimental tasks through motor actions. In addition, they have to search for the tasks that perhaps are delayed in space and time in the gaming environment. These are often more complex than simply chatting, shooting, or regulating experimental simulations, and the completion of the objective may involve several or all of these. The learning objectives of tasks are not obviously given, but gradually unfold while learners interact with the game to complete them. They have to discover and analyze what the learning objectives behind these tasks are. They have to draw hypothetical conclusions from the result of their attempts to solve the task, especially when they have failed to reach their goal and need to repeat the attempt.

Thus, learning with games seems to pose a challenge even to learners with a high level of expertise in the learning topic, and more so to novices. Martens et al. (1997) suggest that learners with higher developed prior knowledge on the learning topic have a better base for compensating for complexity, intransparency, and incoherence within information. They have knowledge structures in long-term memory available, which help to organize and link relevant information. In contrast, novices have no sufficient prior knowledge and corresponding knowledge structures in their long-term memory to compensate for ineffective activity. The provided tasks in games are often too difficult and mentally too demanding for novices. They prevent them from accurately processing the necessary information. As a result, novices might experience a total cognitive load that exceeds their limited working memory capacity and leaves them with insufficient cognitive resources for successful learning. Novices could also revert to less meaningful learning to keep their cognitive load within the threshold limit (Aleven et al., 2003). This attempt to avoid cognitive overload through unselective, explorative modes of information processing is as detrimental to learning as a cognitive overload itself.

For novices, providing support devices might be one possible approach to reducing cognitive stress in terms of task complexity and difficulty. The effectiveness of this approach is supported by research in the field of cognitive load theory (e.g., Chall, 2000; Kirschner, Sweller, & Clark, 2006; Klahr & Nigam, 2004; Tuovinen & Sweller, 1999) but also by theoretical frameworks of classroom teaching (e.g., Klauer, 1985). Moreno (2004) concluded from a literature review of studies comparing pure discovery learning with guided forms of learning that "the debate about discovery has been replayed many times in education but each time, the evidence has favored a guided approach to learning" (p. 18). Game researchers (e.g., Cobb & Fraser, 2005; Leemkuil, 2006; Leutner, 1993; Rieber, Tzeng, & Tribble, 2004; Salzman et al., 1999; Standen et al., 2001) therefore stress the importance of support devices. They may overcome difficulties of task complexity by presenting essential information. They help make the uncovering of relations between the provided learning objects more explicit and transparent (de Jong, 2005). Also, they aim at cognitive processes of learners by directing learners' attention to the essential learning information. Therefore, combined with an adequate game design, they may reduce information search and, consequently, cognitive load in order to enhance the learning outcomes (de Jong, 2005), that is the successful restructuring and integration of new information in existing knowledge structures (Krapp & Weidenmann, 2001). But support devices not only seem to enhance learning outcomes through preventing cognitive overload, they may also strengthen the relation between learners' experience of virtual presence and their learning. Virtual presence is defined as an actual subjective emotion-related state in which a user is fully immersed in a virtual activity provided by technological means. For games, their positive impact on virtual presence was affirmed in several studies (e.g., Heers, 2005; Welch et al., 1996). Furthermore, in the study carried out by Schrader and Bastiaens (2012), it was demonstrated that virtual presence is positively associated with learning success. Adapted from research on emotions in the fields of psychology, education and computer science (e.g., Dweck, 2002; Lepper & Henderlong, 2000) and education (e.g., Ainley, Corrigan, & Richardson, 2005; Meinhardt & Pekrun, 2003; Meyer & Turner, 2002; Pekrun et al., 2002), it was argued that this result is based on virtual presence's function to motivate and stimulate learners to invest mental effort in learning with games. Also, virtual presence guides learners' attention away from the interface towards the gaming content. This increases the cognitive capacity actually allocated to the learning task. However, the findings of the study also showed that virtual presence does not guarantee better learning outcomes. Besides learners' individual tendency to invest in virtual presence, it was shown that a heavy cognitive load, which might be due to inadequate game design and complexity of tasks, reduced virtual presence and its positive impact on learning (Schrader & Bastiaens, in press).

Because of the described benefits of support devices on cognitive load, virtual presence, and learning outcomes, game designers do not always ignore the role of support. An analysis of current support devices in educational computer games reveals a variety of designs (e.g., direct vs. non-direct, game-extrinsic vs. game-intrinsic, before vs. during game-playing, learner-requested vs. automatically system-initiated). All are based on the idea of supporting learners by giving information on the learning topic or gaming behaviour. However, the few existing studies on support devices and their relation to learning outcomes (e.g., Leemkuil, 2006; Leutner, 1993; Nelson, 2007) show that even if support is provided it does not always improve learning outcomes, especially not if learners have a low level of expertise (Nelson, 2007). In accordance with these results, this article argues that support devices are more effective predictors of learning success if they are designed to reduce cognitive load while also enabling virtual presence. Hence, the current article focuses on support devices designed to mediate the embedded learning topic effectively rather than to instruct the learner on how to interact with the gaming environment.

Considering this background, the area of particular interest in this study is on the design of support devices in terms of their types of provision, more specifically on two different types: intrinsic versus extrinsic support. In particular, this study investigates which one of these two types is most capable of maximizing virtual presence and minimizing cognitive load to advance learning outcomes. The type of provision is interesting since advocates of pure discovery learning oppose not only integrating content support into the gaming environment but also take different stances on this issue (e.g., Hofer et al., 1996; Nelson, 2007; Renkl, 2002; Wood, 2001). Besides, especially in the field of educational computer games, consolidated findings are rare.

Therefore, the following section discusses the advantages and disadvantages of the different methodological approaches in the areas of support provision with regard to virtual presence, cognitive load, and learning outcomes.

The Provision of Support Devices: Intrinsic versus Extrinsic

Based on the basic support categories of Gery (1995), an analysis of current support devices in computer games shows that support can be presented in an *intrinsic* or in an *extrinsic* way. Intrinsic support automatically provides learning information during game-playing that is adequate to the learners' actual needs, that is when learners make a mistake (e.g., in *Winterfest* [Alphabit, 2012]). In contrast, extrinsic support is not part of the gaming world. It offers domain-specific background information such as definitions, basic facts, and concepts mostly presented in the form of a hyperlinked textbook (e.g., in *Bioscopia* [Heureka-

Klett, 2011]; *River City* [Dede, Ketelhut, & Reuss, 2003]).

Hofer et al. (1996) suggest that the intrinsic type of support provision – if it is adequately designed (for an overview of design see e.g., Narciss, 2006) – may be more effective for learning compared to an extrinsic hyperlinked textbook. While the authors did not elaborate on possible causes for the learning ineffectiveness of extrinsic support, the effects they observed can be explained with a decrease in virtual presence and an excessive cognitive load. It can be argued that switching between the gaming environment and the extrinsic hyperlinked textbook not only causes a break in the experience in terms of virtual presence. It also requires additional working memory resources unrelated to learning and thereby overloads the limited working memory capacity. Whereas the intrinsic support provides explicit information that helps to continue solving a gaming task, information given in the extrinsic type of support does not necessarily help to make judgements about the actual task in the game. Here, learners have to pause their game-playing for searching of suitable information and have to adapt it to the current task inside the game. Especially for novices, who may not understand or misinterpret the learning purpose of the tasks, it is practically impossible to select the relevant information for a specific learning task at hand. Consequently, they are not likely to profit from extrinsic support in terms of learning.

Besides their difference in spatial presentation and alignment on given tasks, both types also differ in their degree to which the control of support is given to the learners. Whereas intrinsic support is volunteered by the game-system, extrinsic support has to be invoked from the learner. This influences not only virtual presence, cognitive load, and learning outcomes but also the use of help. As highlighted in several studies (e.g., Hofer et al., 1996; Jiang, Elen, & Clarebout, 2009; Nelson, 2007; Wood, 2001), the effect learners' control of support has on learning outcomes may not always be materialized as some researchers stated (Hofer et al., 1996; Leutner, 1993; Renkl, 2002). Nelson (2007), for example, evaluated the influence of learner-requested access to support in a learning simulation, but found no measurable impact on learning. He notes that an important feature of support is that learners are given the choice of whether or not to use it. When support devices are offered for optional use, as in the type of extrinsic support, learners reported lower learning outcomes because instead of using the support device they tried to guess the right answer. In addition, Wood (2001) found that novices are the least likely to use support appropriately when it is under their own control. It was argued that novices have weaker help-seeking behaviour or that they might be unable to cope with the demands of searching for help. They are faced with tasks, which are, given their low prior knowledge, subjectively already difficult enough. Thus, the learning effectiveness of extrinsic support is minimal especially for novices because they do not actively use help as appropriate. Hence, novices have to be provided automatically with intrinsic support, continuously added as learners repeatedly fail at solving a task. This strategy of information delivery would guarantee the appropriate use of the help function by offering the novices assistance tailored to their actual need in a specific situation and, at the same time, prevent overloading the learners' cognitive resources and preserve learners' virtual presence by allowing them to continue concentrating on the current task.

Research Questions

For support devices to be effective in games, the above review suggests that they must be designed to optimize virtual presence, cognitive load, and learning outcomes. Otherwise, support devices may hamper learning. The design of support in terms of their provision should help to meet these requirements. The present research therefore investigates under which type of provision support is most effective in relation to learners' low prior knowledge of the learning topic. In particular, this study addresses the following two research questions.

(1) Are virtual presence, cognitive load, and learning outcomes different for novices who use educational computer games with support devices compared to novices who use an educational computer game without support?

According to this first research question, for virtual presence it is expected that a game without additional support devices generates a higher degree of virtual presence in contrast to both gaming variations with support because game-playing is not interrupted due to offering any kind of help. For cognitive load, it is assumed that both game versions with support decrease cognitive load by providing essential learning information in comparison to an educational computer game without support. Support in general might reduce the search for information and directing working-memory resources to the actual intended learning activity. As a result, both versions with support should increase learning outcomes more than a conventional game version without any support.

(2) Are virtual presence, cognitive load, and learning outcomes different for novices who have access to intrinsic support from those of novices who have access to extrinsic support?

With respect to this second research question, it is expected that intrinsic support enables a more intensive feeling of virtual presence and avoids high cognitive load in contrast to extrinsic support. As discussed in the theoretical part of this article, this assumption is due to the spatial split-attention effect brought about by switching between the game and the hyperlinked-textbook. Moreover, it is expected that game-internal support presents information immediately required to deal with the current task in the game. As a result, intrinsic support is expected to promote learning outcomes more than extrinsic support. The difference in learning outcomes between both support conditions is not only based on the fact that extrinsic support causes a heavy cognitive load when used. Also, lower learning outcomes can be the result of underusing them by learners, even if they require help.

To sum up, the effectiveness of support in games for learning outcomes is hypothesized since it encourage learners to use it and preserves, rather than disrupts, learners' experience of virtual presence. In addition, support devices should reduce cognitive load by implicitly providing help that is adaptive to learners' needs.

Method

Participants

One hundred and thirty-five 8th graders (65 male and 73 female; mean age = 13.44 years, SD = .57) of the preparatory high school Ricarda-Huch Gymnasium in Hagen, Germany participated in this study. As this study examines the effect of support devices on novices, the researchers intentionally selected only learners that were not familiar with the embedded learning topic in the game. Thus, none of the participants had prior knowledge of the learning topic. In addition, participants were not familiar with the educational computer game used in the study. Learners were randomly assigned to one of the following three versions of an educational computer game: (1) without additional support (G) (n = 43), (2) with extrinsic support (G_ES) (n = 47), and (3) with intrinsic support (G_IS) (n = 45).

The Gaming Environment

The computer-based educational game *Elektra* (European commission, 2009) was adapted for this experiment. It offers a coloured, three-dimensional (3D) single-user adventure game for learning physics content for 8th graders. The gaming scenario takes place in an old house in Florence. From a first-person view, learners can move freely through the house's rooms, explore, and manipulate objects to solve learning problems presented to them. They gather information and perform a series of three interactive experimental tasks, through which they can learn, for example, about the concept of light refraction.

For the study, three versions of Elektra were developed: (1) without support (G), (2) with extrinsic support (G_ES), and (3) with intrinsic support (G_IS).

The first design condition, used as the control condition, is the conventional design of a gaming environment. This design follows the tenet that learners should construct knowledge completely on their own by discovery learning, a situation that requires learners to solve the provided tasks without any support. Learners have to learn about light refraction, that is that light consists of rays and how it can be focused. The learner has to send a strong beam of light through the keyhole of a door in order to open it. Behind the door, the beam has to hit a light cell but not anything else. The learner can use a virtual lab with a flashlight and blinds to learn how to create a narrow beam of light and transfer it to the light cell to open the door. If the learner fails in solving the given tasks, no prompts on how to proceed are presented. The learner has to keep trying until the correct solution is discovered (see Figure 1).

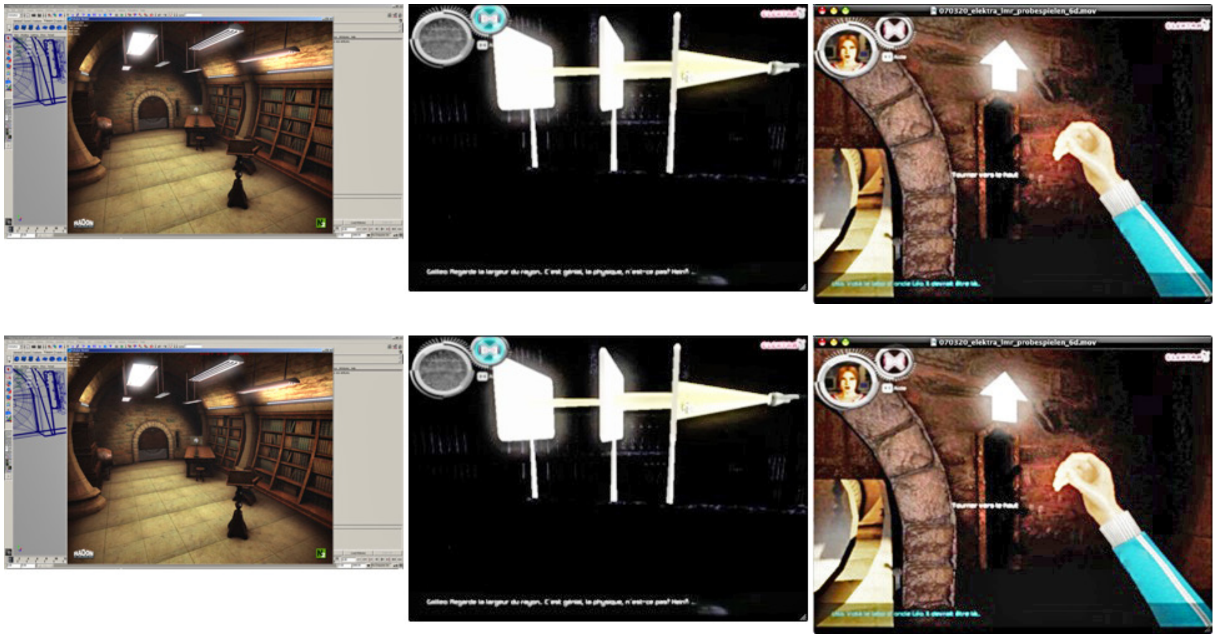

Figure 1. Conventional design of Elektra without support.

The second design condition (G_ES) is similar to the first in that no support is given. Rather, descriptions of the relevant learning concepts are presented in a separate hyperlinked textbook. The learners are made aware of the support device that is always available by a permanently visible button with a hyperlink to the textbook (see Figure 2).

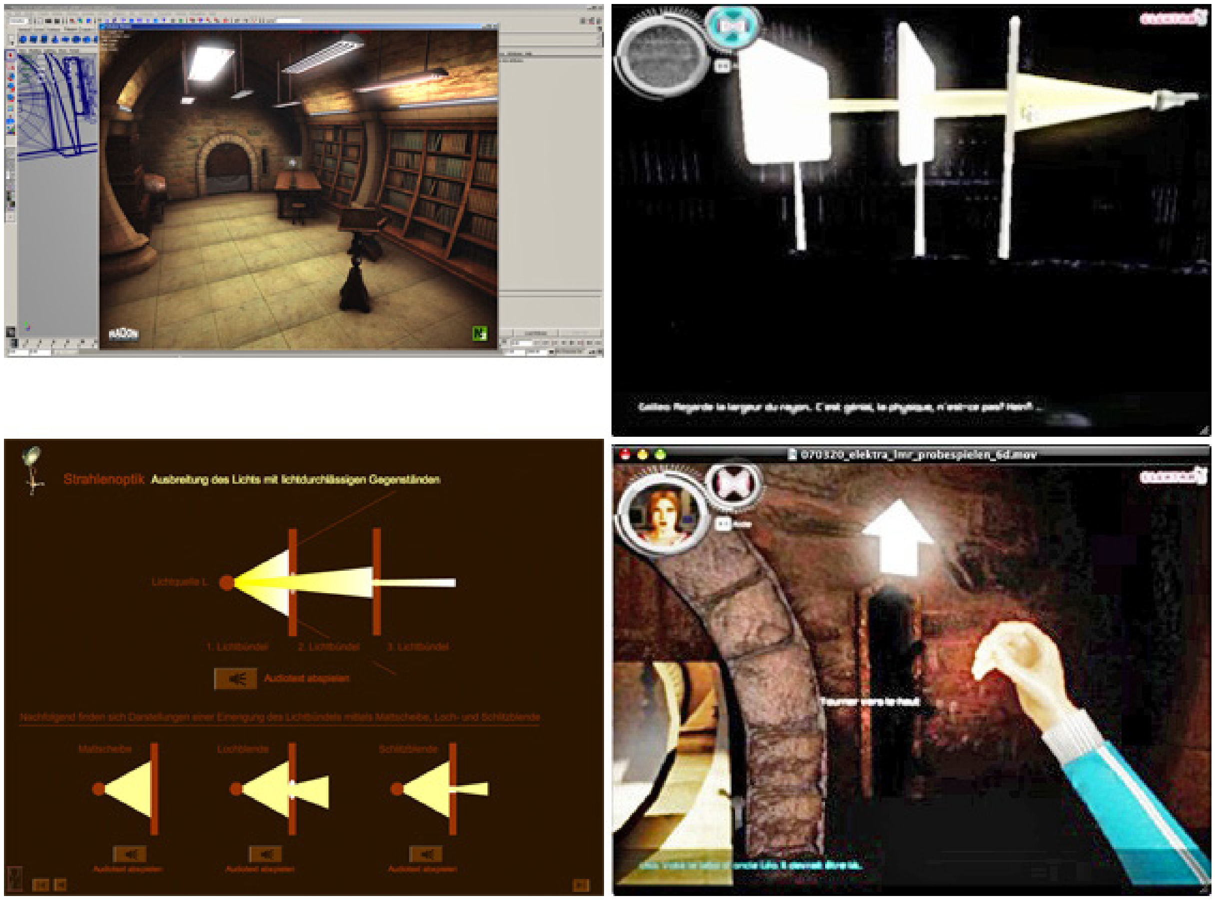

Figure 2. Design of Elektra with extrinsic support in the form of a hyperlinked textbook.

In contrast, the third design condition (G_IS), featuring intrinsic support, provides dynamically embedded support whenever necessary. The system offers support via a pedagogical agent that gives simple hints to encourage learners to keep trying if they have made an error. If a learner repeatedly fails to solve a given learning task, the system provides comments and explanations that contain the correct answer (see Figure 3).

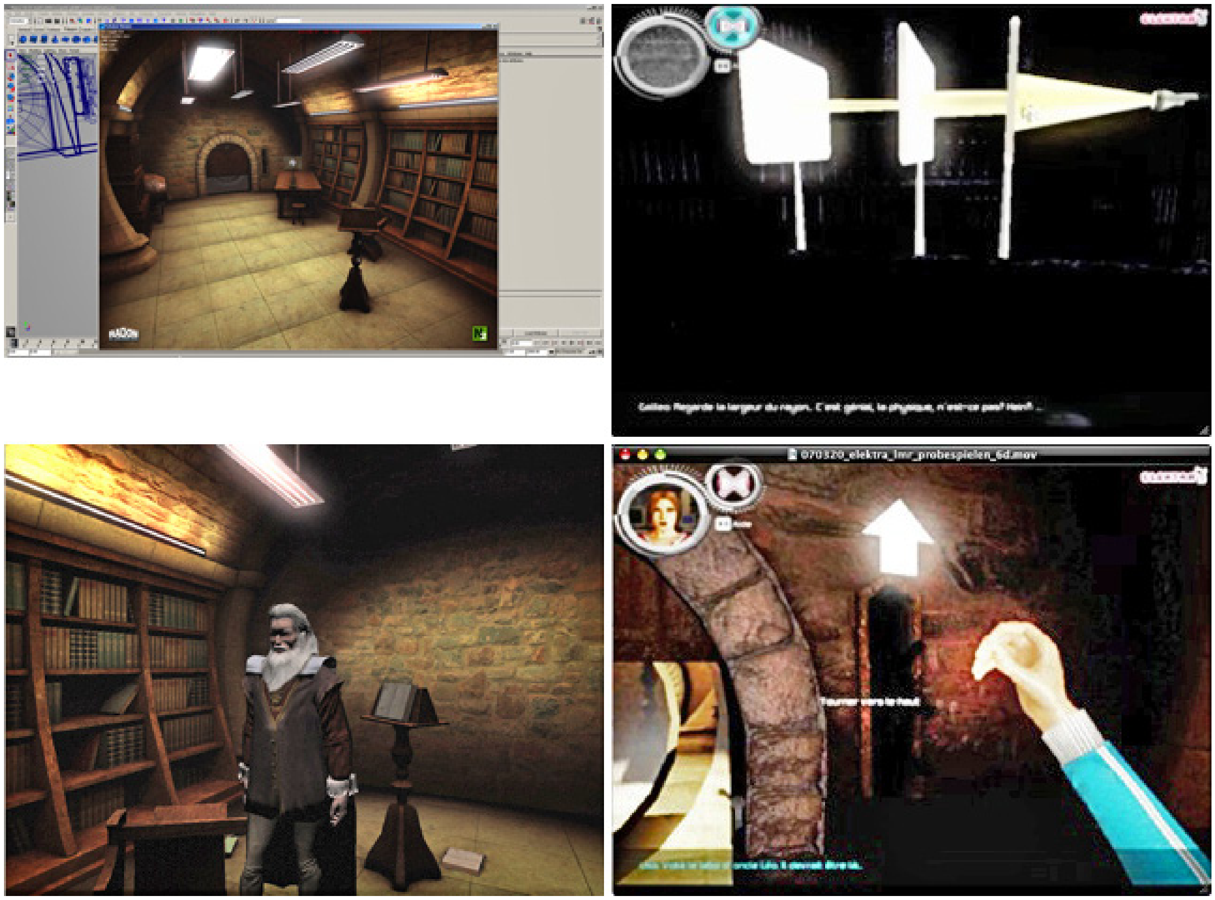

Figure 3. Design of Elektra with intrinsic support in the form of a pedagogical agent.

Measurement Instruments

Background questionnaire.

Before the game-playing experiment started, a background questionnaire was used to gather data on prior knowledge, that is prior knowledge of learning topic physics (3 items), game literacy (1 item), age (1 item), and gender (1 item).

Virtual presence questionnaire.

Virtual presence was measured using Witmer and Singer's Presence Questionnaire (PQ) (1998) that consists of 10 items. Learners rated their virtual presence on a 5-point Likert scale ranging from 1 (*totally disagree*) to 5 (*totally agree*). The PQ measures to what extent learners experienced the feeling of being involved in the gaming environment. The indicators used are the degrees to which they are able to fade out distractions external to the gaming environment, feel in control, and experience their virtual interactions and movements as natural. Due to a low item-scale test correlation one item was not included in the analysis.

Cognitive load questionnaire.

Cognitive load was measured with eight items on a 5-point Likert scale ranging from 1 (*very easy*) to 5 (*very difficult*). One item is the Paas and van Merrienboer (1993) item that is often used for measuring cognitive load in terms of invested mental effort, that is how much mental effort the learner had to invest to complete the learning tasks in the gaming environment. The other seven items are the Kalyuga and Paas (2005) items for measuring perceived levels of difficulty to assess the specific demands on working memory (intrinsic, extraneous, germane load) that resulted from the different requirements of the educational environments or the learning content within them. Five of the eight items were significant with the cognitive load total score ($.52 < r_{it} > .73$). This indicates that it was not possible to separate different aspects of cognitive load affected by different specific demands of the virtual environments and learning tasks within. Thus, the mean of all items as an indicator of overall cognitive load in the data analyses was applied.

Learning outcome questionnaires.

Outcomes concerning the learning topic were measured to assess the differences in retention, comprehension, and near and far transfer. After the questionnaire was constructed, two teachers of physics were asked to review it. Both were assessing the questions in regards to their readability and if they would be understandable and clear for learners at the educational level of eighth graders. Where necessary, the questionnaire was adapted according to their review.

Retention of facts and concepts as a more trivial learning outcome was measured by five multiple-choice questions. Each question was scored with one or zero points according to whether it was answered correctly or incorrectly. The quality of comprehension was measured with four open-ended questions, in which the learners had to demonstrate their understanding of the acquired knowledge in their own words. Here, the maximum test score was one point for each question. The transfer tasks comprised six near-transfer tasks and four far-transfer tasks to measure the quality of the transfer of the acquired knowledge to new situations (for a discussion on differentiating transfer, cf. among others Hasselhorn & Mähler, 2001). The near-transfer tasks were analogous to the learning objects in the game, but contained different objects than those presented in the game (e.g., a match instead of a wooden ball). The far-transfer tasks were different in structural features and were meant to determine whether or not learners were able to apply the acquired knowledge to unknown and more complex situations. For example, a task on magnetism required the learners to explain why one cannot use buttons the size of a coin instead of real coins to pay a parking fee at a ticket machine. Here, the maximum test score was eight points. Due to a low index of task complexity ($p < .20$), one item for retention, near transfer and far transfer was not included in the analyses.

Apart from learning outcomes, game knowledge was measured with 10 questions testing knowledge about the storyline and technical features.

Table 1 shows the scales of the questionnaires, the number of items per scale accompanied by an example of an item, and the reliability coefficients of all scales.

Table 1

The Scales of Questionnaire and their Reliability

Main scale	Items	Example	Reliability
Prior Knowledge	4	My knowledge concerning light refraction is …	.59
Virtual Presence	9	I felt that I was able to control events in the virtual environment (*Involvement and control*) I felt like I was immersed and interacting in the virtual environment (*Involvement and control)* While working in the virtual environment I was able to fade out external distractions (*Distraction*)	.86
Cognitive Load	8	When learning with the virtual environment I invested very low…very high mental effort (*Mental effort*); The physical learning topic was … *(Intrinsic load);* Working with the virtual environment was … *(Extraneous load);* Understanding the physical learning topics and the relation between the three major topics were … *(Germane load)*	.82
Learning Outcomes			
Retention	4	Which objects do magnets attract? Please choose the objects!	.59
Comprehension	4	Why do you think that magnets attract the objects? Please give reasons for your choice!	.60
Near Transfer	5	Which objects do magnets attract? Please choose the objects!	.61
Far Transfer	3	Why can't one use buttons the size of a coin instead of real coins to pay the parking charge of a car?	.59
Game Knowledge	10	Which button does one have to press to get Galileo's support?	.66

Procedure

The study was conducted in the computer labs of the FernUniversität in Hagen, Germany. At the beginning, all learners participating in this study took a self-reported knowledge test about the physics learning content and about the game. Also, demographical data of the participants were collected. Afterwards, learners were randomly assigned to one of the three experimental conditions. Subsequently, the learning phase started, which took one hour approximately. Directly after the exploration, learners filled out the virtual presence and cognitive load questionnaires (15 minutes). These questionnaires were followed by the learning tests (40 minutes).

Analysis

One-factorial analyses of variance (ANOVA) were performed to measure the overall difference in the mean level of virtual presence, cognitive load, and learning outcomes between the groups presented with three different design conditions of the same educational computer game (G, G_ES, G_IS).

As the overall differences between the three groups was significant, analyses of contrasts were conducted to carry out two comparisons: first, between the group who learned with the G version on the one hand and both groups who learned with the support versions (G_ES, G_IS) on the other hand and, second, between both groups with support (G_ES, G_IS). Analyses of homogeneity of variances indicated that for all groups the population variances were equal. Also, all scores were normally distributed. Thus, it was shown that the use of ANOVA and contrast analyses was justified. For all statistical tests, a significance level of .05 was maintained. In addition to the statistical significance, for ANOVA Eta^2 and for contrast analyses $r_{contrast}$ was used as the degree of the effect size showing the practical significance.

Results

The additional analysis of the G_ES group's utilization of the hyperlinked textbook indicates, as was hypothesized, that the textbook was accessed infrequently. Only 30 learners used the linked textbook for help during game-playing, whereas 17 learners reported that they had ignored it. In order not to adulterate the results concerning the effectiveness of support devices on virtual presence and cognitive load, the analysis for the G_ES group includes only the data of the 30 learners who used the textbook. The number of learners that dropped out was evenly distributed over the conditions ($X^2 = .29$, $p = .95$). This resulted in the following group composition: (1) game without additional support (G) ($n = 30$), (2) game with extrinsic support (G_ES) ($n = 30$), and (3) game with intrinsic support (G_IS) ($n = 31$).

There was no statistically significant difference between the three groups concerning gender: (1) male = 13, female = 17; (2) male = 15, female = 15; (3) male = 14, female = 17; $X^2 = .10$, $p = .94$. Also, the collected data for determining learners' prior knowledge showed no differences between learners ($F(2, 88) = .33$, $p = .71$). As well, participant comparability with respect to the learning topic was assured because the presented learning topic of physics is embedded in the school curriculum for eight graders of Gymnasium – the German equivalent of the British grammar school or US preparatory high school – and all participants were only at the beginning of their eighth year. In addition, learners had no previous experience of the used educational computer game Elektra. Thus, these results ruled out the possibility of a prior knowledge effect connected to the given learning topic or the game.

The mean results for virtual presence, cognitive load, and learning outcomes are summarized in Table 2.

Table 2

Means (and Standard Deviations) for Virtual Presence, Cognitive Load, and Sum Scores for Learning Outcomes of the Three Groups

	G (*n* = 28)	G_ES (*n* = 30)	G_IS (*n* = 31)
	M (*SD*)	M (SD)	M (*SD*)
Virtual Presence	3.90 *(.80)*	2.95 (.76)	3.56 (*.84*)
Cognitive Load	3.71 (*.82*)	3.56 (.86)	3.44 (*.76*)
Learning Outcomes			
Retention	.82 (*.54)*	1.69 (.98)	2.00 (*1.01*)
Comprehension	1.28 (*.58*)	1.96 (.81)	2.20 (*.98*)
Near Transfer	2.60 (*1.44*)	3.70 (.95)	3.78 (*1.16*)
Far Transfer	.78 (.24)	1.20 (.32)	1.24 (*.80*)
Game Knowledge	9.57 (1.83)	9.50 (2.08)	9.50 (*2.30*)

Virtual Presence

Concerning virtual presence, the means in Table 2 shows that the G group obtained a mean score of 3.90 (SD = .80), the G_ES group a mean score of 2.95 (SD = .76), and the G_IS group a mean score of 3.56 (SD = .84). These differences were statistically significant (F(2, 88) = 11.03, $p < .05$, $n^2 = .20$). Additionally, separate analyses of contrasts confirmed the general hypothesis that the G group differed in its virtual presence from both groups that were provided with support. The conventional version of the educational computer game without support devices increases virtual presence significantly above the levels of virtual presence seen in both groups that used support versions (t(88) = 3.52, $p < .05$, r = .35). Moreover, a significant effect was found for the comparison between both groups with support devices (t(88) = 3.00, $p < .05$, r = .30), that is the rated feeling of virtual presence was higher in the G_IS group than in the G_ES group.

Cognitive Load

According to the means, the G group reported the highest mean of cognitive load, whereas the G_IS group demonstrated the lowest mean of cognitive load during game-playing. The G_ES group's reported mean was at the centre. The results of the one-way ANOVA to check the statistical differences among the groups, however, demonstrated that there is no significant difference in cognitive load among the groups (F(2,88) = .77, p = .46).

Learning Outcomes

Differentiating the learning outcomes for the learning topic of physics in terms of retention, comprehension, and near and far transfer, the G group reported the lowest sum scores in learning outcomes compared to the G_ES group and the G_IS group. The difference in sum scores between all three groups was statistically significant for retention, comprehension, and near transfer (for retention: $F(2,88) = 11.17$, $p < .05$, $n^2 = .20$; for comprehension: $F(2,88) = 5.65$, $p < .05$, $n^2 = .11$; for near transfer: $F(2,88) = 8.78$, $p < .05$, $n^2 = .16$), but not for far transfer ($F(2,88) = 1.44$, $p = .24$). In addition, analyses of contrasts showed that the G group differed in these learning outcomes from both groups that were provided with support (for retention: $t(88) = 4.59$, $p < .05$, $r = .43$; for comprehension: $t(88) = 3.27$, $p < .05$, $r = .32$; for near transfer: $t(88) = 4.17$, $p < .05$, $r = .40$). The contrast analysis of the comparison between the G_ES group and the G_IS group demonstrated nonsignificant effects (for retention: $t(88) = 1.20$, $p = .22$; for comprehension: $t(88) = .85$, $p = .39$; for near transfer: $t(88) = .29$, $p = .77$; for far transfer: $t(88) = 2.74$, $p = .07$).

For game knowledge, the results reported a contrary effect than for the outcomes of the learning topic: Although the difference in sum scores of gaming knowledge was not significant between groups ($F(2,88) = .01$, $p = .98$), the differences in the sum scores nevertheless demonstrated that learners in the G group reported higher game knowledge than did learners who learned with the G_ES version and learners who learned with the G_IS version.

Discussion and Conclusion

Based on criticism of tenets of pure discovery, problem-based, and experiential learning, this study compared the effects of educational computer games with different designs of support devices. The study focussed on computer games with intrinsic or with extrinsic support. The study measured the influence the type of support system has on virtual presence, cognitive load, and learning outcomes and compared these results to the influence of conventional educational computer games without any support devices.

Results show that the effectiveness in terms of virtual presence was influenced both by the presence of support devices in educational computer games and their design as well. As expected, learners who learned with the conventional educational computer game reported the most intense experience of virtual presence because they were not interrupted in game-playing by support devices. The comparison of both groups using support devices demonstrates that the group who learned with the educational computer game with intrinsic support reported a more intensive virtual presence than the group provided with the support device in the form of an extrinsic hyperlinked textbook. This result confirms the hypothesis that virtual presence is diminished by the break in learners' game-playing in order to search for support in the hyperlinked textbook. According to these results, support devices are more effective in terms of virtual presence if they are intrinsic, that is integrated into the gaming environment.

Moreover, intrinsic support was hypothesized to have a positive influence on learning outcomes not only by enhancing virtual presence, but also by avoiding heavy cognitive load. However, for cognitive load, the theoretical hypothesis was not confirmed. All three game conditions do not significantly differ in affecting cognitive load. This result shows that support devices can affect the demand on cognitive processes not only in a positive, but also in a detrimental way. This might support the idea that even if support provides useful information for solving the given task, it also causes cognitive effort for novices, who have to deal with both the task and the help simultaneously. This explanation, in addition to the fact that cognitive load is neither affected by the use of support devices nor by their implementation, also accounts for the observation that not all learners used learner-requested extrinsic support. In accordance with the theoretical assumption that especially novices do not use support devices because they might be unable to cope with additional information (Wood, 2001), the additional analyses show that 17 of 47 learners ignored the extrinsic support device. It can be argued that these learners refrain from requesting support in order to avoid cognitive load and to preserve their virtual presence and involvement in the gaming environment. Whereas Aleven et al. (2003) suggest that an appropriate design of support might compensate for the cognitive load of its use, in our study the cognitive load was not reduced by the support device designed to eliminate additional cognitive load by integrating the help into the gaming environment. A reason for this finding could be due to the design characteristics of the given extrinsic support. The possibility of stopping the game to search for help outside (i.e., not doing game-playing and help-searching simultaneously) might have prevented the expected cognitive load. While the results discussed suggest no significant difference in cognitive load between all three game-design versions, support seems to be effective in terms of learning outcomes. Based on this result, a straightforward practical implication of this study is that support should be provided within educational computer games. Learners with access to support, regardless of its design, showed significantly greater gains in test scores for retention, comprehension, and near transfer compared to those with no access to support in the conventional gaming condition. For far transfer as a nontrivial and more complex learning outcome, the hypothesis of improved learning outcomes due to support in general could not be confirmed. Nevertheless, given the low test score for learning outcomes in terms of retention, comprehension, near and far transfer, any interpretation on the basis of learning effects should be considered with caution. Contrary to the significant differences between the group presented with the conventional educational computer game on the one hand and both groups with support devices on the other, the differences in design between both support devices did not have any measurable effect on learning outcomes in terms of retention, comprehension, and near transfer. Dochy and Segers (1997) provide a possible explanation for this finding. The authors hold that in classroom practice a high level of interest strengthens the relation between prior knowledge, the use of support, and learners' mental effort. Adapting this result to our study, it can be assumed that the group using the extrinsic support device had a higher level of interest in the given learning topic and/or in learning through gaming than the other two groups. This assumption can be supported by the fact that only the results of subjects who used this type of support provision, thereby showing a high level of motivation, were taken into account. Thus, this group may have used support in a more adaptive way because its members wanted to master the tasks. They may also have invested more mental effort, that is they may have allocated more cognitive capacity to the task and may therefore have had improved learning outcomes.

In summary, educational computer games with support devices enhance learning outcomes compared to educational computer games without additional support. However, dependent on the level of learners' interest, the type of support provision may or may not have an influence on learning outcomes. In order to gain a thorough understanding of the impact of learners' level of interest on the effectiveness of types of support provision, more research needs to be conducted. In order to learn more about the effect of learners' characteristics on the effectiveness of support in games, subjects need to be not only selected in such a way as to ensure sufficient variation in their levels of interest (e.g., in the learning topic, in learning with games). Also the differences between novices and experts should be studied since experts are better able than novices to compensate for design flaws of support devices and to integrate new knowledge. Such studies should be conducted with respect to novices' and experts' respective experience of virtual presence and cognitive load and to the learning effectiveness of different support designs. Since it was not possible to differentiate between the three cognitive-load types in measuring them, which is the first limitation of this study, future research on cognitive load needs to use instruments that distinguish the three cognitive load types, instruments that were not available to the researchers of the present study (see, for discussion, e.g. Domagk, 2009). This is not only necessary to gain insight into the influence of differently designed support on cognitive processes, but also to investigate more thoroughly whether or not cognitive load regulates the relation between support, virtual presence, and learning outcomes. Another limitation of this study is the relatively low number of participants, which may have had a negative effect on the statistical power. Thus, future research should use larger samples. Furthermore, the reliability of the retention and far-transfer tasks was slightly below the accepted consistency of measurement (i.e., Cronbach's $\alpha = .59$). This seems to indicate that not all tasks assessed learners' knowledge and understanding of the given physics material. Based on the fact that the average correlation between items for retention and transfer was as respectable ($r > .300$, see Field, 2009), however, data from both questionnaires were used. Finally, it was not possible to determine how frequently and for how long learners used the extrinsic support in the G_ES group. Therefore, it cannot be excluded that some learners did not follow the instruction to use the hyperlinked textbook when needed, although they said so in the questionnaire. It may be possible that they gathered no additional information similar to learners provided with no additional support. Further studies should include log-file data of the use of extrinsic support (e.g., when and how learners use certain support-options during learning with games) combined with direct observations (e.g., eye-movement, think aloud-interviews) that could provide useful information on whether and how often support devices were properly used.

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