VIDEO-BASED LEARNER ASSISTANCE IN LEARNING ENVIRONMENTS FOR GEOMETRY

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Learner assistance is a fundamental element if Interactive Learning Environments (ILE) that can be given in the form of Worked Example Videos (WEV). We developed an ILE according to five research based guidelines that integrates WEVs. These support learners in learning geometry on interactive work sheets that are based on Dynamic Geometry. In our study we found that students intuitively use the ILE, its interactive geometrical construction tools and the WEVs. We argue that metacognitive help seeking skills are a fundamental but often neglected factor for an effective usage of learner assistance. We further assume that WEVs have the potential to support learning geometry if adequate help seeking skills are available and the learning environment is designed according to our research based guidelines guidelines.

AIMS & BACKGROUND

The goal of our research project concerning the learning of geometry with interactive media was to develop and evaluate an *Interactive Learning Environment* (ILE) that provides learner support in the form of interactive videos. This ILE should include interactive work sheets based on the Dynamic Geometry Environment (DGE) *Cinderella2* that give learners adequate feedback of their activities. Though the ILE should enable students to work self directed and activate meaningful cognitive processes (increase *germane load*, Chandler & Sweller, 1991). To achieve this we worked on a theory grounded framework that integrates results about learning with worked out examples (Renkl, 2002; based on the *Cognitive Load Theory,* Chandler & Sweller, 1991) and about learning with interactive videos (Riempp, 2000). Worked out examples and interactive videos both have the potential to lower extraneous cognitive load and activate a learner's cognitive activity. We combined these ideas by creating so called *Worked Example Videos (WEV)*. WEVs are one form of *Multimedia Learner Assistance (MLA)*. Such learner assistance is essential in ILEs students are unfamiliar with.

In two empirical studies we observed if and how students used different kinds of MLA and how useful and effective MLA was for their learning process. We wanted to know if design and structure of the new learning environment as well as WEVs are well accepted by learners. Our leading questions were: How can we support geometrical thinking and learning in the case of construction and variation problems? How effective is learning supported by WEVs? Has MLA the potential to enable students to learn self directed? What implications can be made for the usage of ILE in classroom? In this paper we concentrate on the students' usage of WEVs, their help seeking behaviour and their working styles.

THEORETICAL FRAMEWORK

The main conceptions of learning with worked examples (Renkl, 2002) and of learning with interactive video (Riempp, 2000) form the frame for the idea of learning with WEVs. For our research project this frame had to be supplemented with mathematical contents. We focused on geometrical construction tasks as the solution of a construction task always is a process that consists of a *sequence* of single construction steps. Such a process, where every step follows a previous one until the solution is found can perfectly be visualised by video, which is nothing else but a *sequence* of images. On the other hand the visualisation of a solution process in form of an animation or video can be considered as a worked example of the construction task and is called WEV. A WEV for learning with digital tools like DGEs is the *screen recording* of an expert's solution of the task[1]. Such videos provide instructional support to learners who can use them in an interactive way, namely they can use all functions of a media player like play, pause or the search bar.

Interactive, Web-based Work Sheets

The substantial elements of the ILE are video enriched, interactive work sheets. In short an interactive work sheet is a webpage including a Java applet that offers a geometrical task, for instance a construction task. So it takes advantage of a number of features and potentials of DGEs (e.g. Laborde *et al.*, 2006; Jones, 2002). DGEs in their 'natural' form are very open tools with a high number of functions and tools. This leads to high demands on student's concentration and can lower their learning outcomes (Hölzl, 1999). One possibility to deal with this problem is the usage of interactive work sheets. With the DGE *Cinderella2* it is easy to produce such interactive, web-based work sheets. These are web pages including a Dynamic Geometry applet which allows direct manipulation. So learners can use the drag mode and experiment with ready-made geometrical constructions. Further the developer of an interactive exercise can provide a selected number of construction tools to enable users to construct geometrical constructions on their own. Additionally *on-demand help* can be provided in text form (as hints) or in the form of insertion of construction elements. By the help of *Cinderella's* "Automatic Theorem Proving" this help is intelligent and case sensitive (Kortenkamp & Richter-Gebert, 2004). It provides feedback, which plays an important role for self directed learning with DGEs (Jones, 2002). Laborde *et al.* (2006) stress the role of feedback as well, namely the potential of feedback in the learning process and its impact on learning. They argue that students must receive adequate feedback to see their failure or to be confirmed when they are on the right way. Based on these results we conclude that one of the most important factors in the development of an ILE is providing adequate feedback and support to learners.

Multimedia Learner Assistance in ILEs

In our ILE we offer a set of MLA containing: (1) on-demand help in form of hints and insertion of geometrical objects, (2) intelligent feedback in text form and by the colouring of special elements, (3) support for tool usage in text form and as animated demonstration and finally (4) worked examples as dynamic constructions and as WEVs. Every interactive work sheet includes these forms of MLA and can be requested by the learner. In the frame of learning geometry with interactive work sheets some types of MLA already have been discussed like colouring, graphical or textual feedback (Heintz, 2000). The new element in our ILE, the WEV has not yet been in the focus of research.

To benefit from the potential of a construction tool, a learner needs knowledge of both, mathematical understanding and of the tools functions and potentialities. We accommodated this by supporting both: support in the case of mathematical problems is given in the form of worked out examples; the acquisition of knowledge of tool functions and tool usage is supported by tool support. As we concentrate on support via interactive video, problem support is given by *WEVs* on the one hand and tool support by *animated demonstrations* on the other hand[2].

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[1] Research on learning with worked examples shows, that the provision of worked examples can lower extraneous cognitive load, so that cognitive capacity becomes free for meaningful learning (Renkl, 2002).

[2] An *animated demonstration* is the dynamic visualisation of the process of employment.

We assume that especially MLA for tool support can also foster and shorten *instrumental genesis* (e.g. Vérillon & Rabardel, 1995). This will be a leading issue for future research.

Guidelines for Interactive Work Sheets

We developed an ILE according to five principles that result from our framework. For ILEs with video enriched interactive work sheets and integrated worked examples we formulate the following research based guidelines:

- (G1) Reduce the interface; make sure that your ILE has elements the learner is familiar with; don't forget the "Undo"-function.
- (G2) Provide feedback for self monitoring and performance control.
- (G3) Reduce extraneous load by offering learners support in the form of worked examples.
- (G4) Increase germane load by activating meaningful cognitive processes, e.g. with a high degree of interactivity (Schulmeister, 2003).

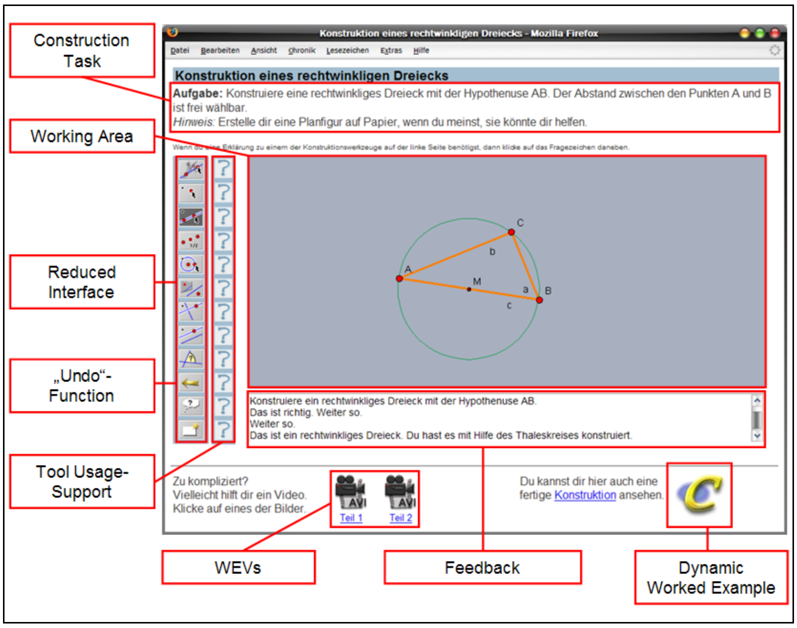

Figure 1: Design of an Interactive Work Sheet

- (G5) Support learners in their usage of the new ILE, especially in their tool usage (support the instrumentation process), e.g. by offering animated demonstrations.

Figure 1 illustrates an example of an interactive work sheet that was designed according to these principles.

Help Seeking in ILEs

Learner support is an important goal of the ILE as it appears in guidelines (G2), (G3), (G5) and indirectly in (G4). A problem that arises from this is the fact that the usage of support or help is an activity that requires metacognitive *help seeking skills* (Aleven *et al.*, 2003). These skills can be subsumed under a model of help seeking behaviour as described by Aleven *et al.* (2003). This model is made up of five steps: "1. Become aware of need for help. 2. Decide to seek help. 3. Identify potential helper(s). 4. Use strategies to elicit help. 5. Evaluate help-seeking episode." (Aleven *et al.*, 2003, S. 281) To be effective in help seeking one has to complete these steps successful. A special case is help seeking in ILEs. Aleven *et al.* (2003) assign the help seeking model for this case. The steps of the new model stay the same, but they can get a different character. We can not go into detail here but want to stress some important aspects. When learning with ILEs some obstacles may disappear when learners have to decide to seek help. In the classroom they may have fear to ask a teacher or peers for help for quite a number of reasons, which are not relevant in ILEs. Another aspect is the fact that students often have more "potential helpers" in ILEs than in a social context, because the "social context helpers" (teacher, peers, textbook, ...) often are still available, e.g. when working in the computer room. "On the other hand, the help content that ILEs offer, especially when it is context sensitive, may be of higher quality than that offered by peer helpers, for example, who sometimes do little more than type in the correct answer without further explanation." (ibid., p. 282)

Aleven *et al.* (2003) stress that student's help seeking behaviour often is very ineffective. Although if they decide to seek help and identify potential helpers they still may have problems with an effective use. But Aleven *et al.* (2003) also found encouraging research results. E.g. they refer the study of Renkl (2002), who showed that on-demand help leads to better learning results.

METHOD

The video format plays three different roles in our study. At first it provides support for the solution of geometrical problems in the form of WEVs. Secondly it supports the process of acquiring knowledge of the tool use (*instrumentation*) by offering animated demonstrations. Thirdly we use video as a methodological instrument. To get an insight in the student's usage of our ILE we conducted a study, in which students worked individually with the environment. Thereby we observed their behaviour in two ways: (1) A learner's mouse and on-screen activities were recorded via screen recording. (2) Face and torso of each learner could be taped by a web-cam. Both videos were synchronized. The set of data was completed by a computer self efficacy questionnaire, a pre test, a post test and a delayed post test to get information about their mathematical performance before and after the work with the ILE.

For our studies we chose five construction tasks concerning the *Theorem of Thales* [1], which is an essential part of the German mathematics curriculum. These tasks were implemented in the ILE in the form of interactive work sheets. The students' work was supported by different kinds of MLA, a supervisor only was allowed to intervene on technical problems. Students first had to construct a right triangle, then a square, a kite, a rectangle and the line tangents to a given circle. An example for one of the tasks was as follows: "Given the diagonal AC. Construct a square ABCD by using the Theorem of Thales. The distance AC is variable". In this phase of our study 32 students of the 8th grade (13 to 14 years old) participated[3]. It is important to mention that these students were unfamiliar to Thales' Theorem before.

RESULTS AND DISCUSSION

We obtained 26 sets of data out of the 32 students for our analysis. 20 of the students learned individually, 12 in pairs. The lengths of the recordings range from about 25 up to 55 minutes. We report on some striking results.

Intuitive and Problem-Free Use of the ILE and WEVs

Heintz (2000) and Hölzl (1999) refer on problems that arise with the application of DGEs in the classroom. Due to the new medium and the use of DGEs new technical problems appear and these can have negative influence on the learning process. Another aspect is the large number of available tools that can lead to a high cognitive load, which leads to lower learning results (Hölzl, 1999; Chandler & Sweller, 1991). The design of our ILE has some similarities to the one that was successfully adopted by Heintz (2000). By providing students interactive work sheets instead of "full" DGE's we reduced the number of tools to twelve to reduce technical problems with the environment and to lower the demands on students' concentration. A further reduction of technical problems and reduction of (extrinsic) cognitive load (see Chandler & Sweller, 1991) could be achieved by the design of our ILE namely by

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[3] In a second phase with 139 students of the 7th grade of German secondary schools we followed a quantitative approach. The students had to work on six construction tasks and three variation tasks in a classroom situation. In this phase we collected out data with pre and post test, but without video recordings.

providing MLAs and WEVs. Comparably to the results of Heintz (2000) we also could observe nearly no technical problems. As a DGE's construction tools are artefacts, the reduction of tools is a method to make instrumental genesis less complex and to ease the tools' instrumentation (especially with the use of the animated demonstrations).

Furthermore it was eye-catching how students intuitively used the learning environment, especially the interactive work sheets and the available assistance (cp. Mann & Ludwig, 2007). The entrance in the environment in most cases took place very effortlessly and impartially. Also the usage of the WEVs took place very smoothly and most students interacted with the video by using the media player's functions. We claim that a lengthy introductory phase for the tool and the ILE is no longer necessary, if the ILE is designed according to our guidelines. We further assume that well designed learner support by MLA enables students to learn self directed. The students' self-assessment of the assistance received by the WEVs was very positive. All participants made use of them. 24 of 29 students[4] estimated it as helpful; four rated it as partially helpful. For only one of them the video was not helpful. Thus we argue that students accepted the videos and the assistance given by them very well.

Help Seeking

We could monitor help seeking behaviour according to the model by Aleven *et al.* (2003). We found problems occurring on each step of the model. So we see students sitting in front of their screen, staring at it and doing nothing[5]. It was obvious that these students needed support either to get along with special tools or with the geometrical problem. But they either did not become aware of their need for help or they refused to seek help or they could not identify potential helpers. Our observation alone does not always (give clear advice) show evidence?? at which step of the help seeking model the students got stuck. But for most of them it was enough to give a short hint ("You are offered learner support in the environment. Make use of it!") and he or she could solve the problem. For these learners we found a lack of metacognitive help seeking skills that hinders them to solve the tasks. We conclude that it is important that teachers as well as the designer of ILEs are aware of this lack. This result gets confirmed as we have clear advice that students, who used MLAs, performed better in the post test than students who refused to[6]. On the other hand we could observe students who reached step 5 in their help seeking episode: some students changed their working style or changed the requested type of assistance if one kind of MLA was seen as not useful as it did not help to solve a special problem.

Aleven *et al.* (2003) discuss learner related factors (e.g. prior knowledge, metacognitive skill, gender) as well as system related factors and the interactions among them, to see what factors lead to productive help seeking. Besides these factors social factors might play a role. We found clear advice for different help seeking behaviour when learning activities are carried out individually without social context and within social context (e.g. in the classroom).

Learning Strategies and Working Styles

In the last section we skipped step 4 of the help seeking model. But we also made observations on that level of students' help seeking episodes. Step 4 concerns the use of strategies in help seeking (Aleven *et al.*, 2003). Besides the help seeking strategies we see different working styles of students concerning the usage of worked examples to solve a task.

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[4] Unfortunately not all students answered all questions.
[5] We found this behaviour in the second phase even to a greater extent.
[6] This is a first result of the second phase of our study.

We subsumed these working styles and the help seeking strategies under *learning strategies*, of which we could identify seven. Among them strategies that were developed independently by different students.

For instance we have a look at the student M1 (male, 14 years). We recorded and analysed his mouse actions namely the movement of the mouse pointer and his mouse clicks while he was working with the ILE. Altogether he was working for 23:51 minutes on the five tasks. At first he tried to get a general idea of what the environment is made up of (0:08 – 3:46 min). He moved the mouse pointer over the "question marks" for tool support (see figure 1), clicked on them but he didn't read the whole text in the pop-up windows. His goal was to get an overview, so that he later (when working on the task) knew, where to look for help. We could say that M1 identifies potential helpers without needing help. We see a very systematic and well structured approach, which we could identify by other students as well. In his overview he also watched the complete WEV (1:50 – 2:31 min) and so already knew one solution of his first task. But before working on it, he investigated the remaining elements (3:38 min). Then he started to solve the first construction task (3:46 min). With exception of a technical problem with the ILE, he succeeded with the solution in a very unproblematic way (4:17 – 5:01 min). In this phase he used tool support once, but just to see, which construction tool was symbolized by an icon. Although M1 never worked with a DGE before, he seemed to be quite familiar with the ILE and its DGE elements. After finishing the first task he put his solution to paper, as we could see on our webcam recording.

As M1 had used the WEV with success he further used WEVs systematic. He started working on task two by reading it ("*Construct a square with the given diagonal AC*", 5:45min), was thinking about it for some seconds (5:51 – 5:59 min) and performed a first step of his solution (midpoint of AC, 6:00 – 6:04 min). Then he was thinking again for a very short time and started the WEV afterwards (6:09). He just watched some steps of the expert's solution (6:47 min), imitated these steps on his interactive work sheet and then finished the construction 'on his own'. We assume he already anticipated the solution at the point where he stopped the WEV. This assumption gets confirmed as M1 repeated this procedure in the next task. In contrast he watched the complete WEV to task 4. Here he did not anticipate how to finish the construction until he watched it. Altogether we have to different *learning strategies* by using WEVs: (1) Watch the complete solution process and then imitate or reconstruct it. (2) Watch only some (crucial) steps of the solution and construct the rest on your own. (3) Watch the first step; press the pause-button; reconstruct the step; watch the next step; press pause; reconstruct and so on. Strategy (3) was not adopted by M1 but by other students. Another usage of WEVs that could be discovered was the use of the video as *feedback* or *confirmation*. Students who used it this way first solved a task on their own and then watched the WEV to check their own solution by comparing.

We found that some students employed their strategies task specifically and others who maintained their learning style over their whole work. On the other side we found students, who used a strategy as long as it failed and then changed or adjusted it.

Learner's Activity

In all our studies we could find the encouraging effect that learners always became activated through the use of videos and by the high degree of interactivity (Schulmeister, 2003). E.g. after watching a WEV every student tried to re-construct the solution on his or her own. This confirms the activating effect of interactivity – especially on a high level of interactivity.

CONCLUSION

We reported on the first phase of our study, in which we developed research based guidelines for an ILE to supports learners with the help of learning videos. We developed an ILE according to these guidelines and conducted an empirical study with it. We found that the usage of the ILE is very intuitive and unproblematic in cases where students make use of MLA. In general, students who refused to seek help miss metacognitive help seeking skills. We further could observe that students, who work individually and self directed not only have individual working styles but develop special learning strategies that seem to be adopted by special types of learners. Prospective research work will have a look at factors that influence student's performance on construction tasks on the one side and on the other side have a closer look on instrumental genesis in the frame of assignment of learning videos.

NOTES

1. In Germany the "Theorem of Thales" says that if one constructs a triangle in that way, that the hypotenuse is the diameter of a circle and the third point is on this circle, then the triangle is rectangular.

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