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Progression in Multiple Representations: Supporting students' learning with multiple representations in a dynamic simulation-based learning environment

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Introduction

By using multiple representations in simulation-based learning environments, learners are assumed to gain deeper knowledge about a domain and therefore to be able to use their knowledge in other learning situations. Mental transference between representations forces learners to reflect beyond the boundaries and details of the first representation to anticipate on correspondences in the second (Petre, Blackwell, & Green, 1998). However, to be able to learn from multiple representations, learners have to: (1) understand the syntax of each representation; (2) understand which parts of the domain are represented; (3) relate the representations to one another if the representations are (partially) redundant; and (4) translate between the representations, that is, interpret similarities and differences of corresponding features of two or more representations (van der Meij & de Jong, 2006).

An important requirement for learning with multiple representations in simulation-based learning environments is how to support learners in the processes of relating and translating. Both integration and dynamic linking of representations (Ainsworth & Peevers, 2003; Chandler & Sweller, 1991; Mayer & Moreno, 1998; van der Meij & de Jong, 2006) are of proven value. Physical *integration* of representations can make relations between representations explicit for the learner (e.g., Chandler & Sweller, 1991). Integrated representations appear to be one representation showing different aspects of the domain. For simulation-based learning environments with dynamic representations (representations that change over time or change according to input of the learner), *dynamic linking* can be provided to make the relations between different representations explicit for the learner (Ainsworth, 1999). With dynamically linked representations, actions performed on one representation are automatically shown in all other representations.

Another way to support learners in simulation-based learning environments, is providing model progression (White & Frederiksen, 1990). Model progression sequences the learning environment from simple to complex. This study was a first attempt to relate model progression to representational progression. Based on the model progression used, we increased the number of representations iteratively. As a result, the number of relations and possible translations increased likewise. Starting with a few relations and possible translations and then introduce more relations and possible translations step-by-step might support learners in relating the representations and translating between them.

Research questions

The goal of this study was to determine if sequencing dynamic representations has an effect on learning outcomes. The context of the study was a guided discovery simulation-based learning environment called Moments. Students studied the ‘moments’ topic in mechanical engineering with multiple representations of an open-end spanner tightening a bolt. Two versions of the same simulation-based learning environment were compared: a learning environment providing the learners with representations introduced step-by-step (experimental condition) and a learning environment presenting all the representations at once (control condition).

Method

Subjects. The subjects were 120 students from secondary vocational education (aged 15 to 21). They were in their first year of either a course in mechanical engineering or architecture. A between subjects design was used, in which participants were randomly assigned to one of the two experimental conditions.

Learning environment. Subjects worked with the Moments learning environment that was built in the SimQuest authoring environment (van Joolingen & de Jong, 2003). Subjects studied the moments topic in the context of mechanical engineering. Supported by assignments, the subjects could perform experiments in the learning environment. The assignments stimulated the subjects to explore both the relation between the variables in the simulation model and the relation between the representations given. In the experimental condition the following representations were introduced one by one: (1) a concrete representation of an open-end spanner; (2) a diagrammatic representation; (3) a numerical representation; (4) a dynamically changing equation and; (5) a dynamically changing table. In the control condition all five representations were introduced at once. Representations 1, 2 and 3 were integrated. Representations 4 and 5 were dynamically linked to the integrated one.

Procedure. The experiments were held at the participating schools and consisted of three experimental sessions: pre-test, working with the learning environment and post-test. The pre-test consisted of 20 items, both multiple choice and open answer items; 10 items testing domain knowledge and 10 items testing understanding of the domain. The post-test consisted of 40 items. The first 20 items corresponded with the pre-test items. The post-test items differed slightly from the pre-test by differing the item and alternative answer orders. Since subjects did not know which items had been changed, they could not rely on a memory strategy. In addition, 10 tested the ability to relate representations and 10 items tested the ability to translate between representations. The relate items asked students to relate similar variables of representations with different representational codes. To be able to answer translate items correctly, the subjects had to make a mental translation from manipulations on one representation to the effects in another representation, having a different representational code.

Results

One-way ANOVAs showed no significant differences between the experimental conditions on pre-test domain scores and understanding scores ($F(1,118) = 2.68$, $p = .10$; $F(1,118) = .04$, $p = .85$). The overall mean score on the pre-test was 10.32 out of 20 test items ($SD = 3.10$). The overall mean score on the post-test domain plus understanding items was 12.08 out of 20 test items ($SD = 3.10$). A repeated measures ANOVA showed the overall combined domain and understanding post-test score of the subjects was significantly better than the overall pre-test scores ($F(1,119) = 67.38$ $p < .01$). Repeated measures ANOVAs per item category showed the post-test scores on domain and understanding items were significantly better than the pre-test scores on these item types ($F(1,119) = 61.66$, $p < .01$ and $F(1,119) = 22.57$, $p < .01$). The mean scores on the relate and translate items were 8.03 ($SD = 1.47$) and 3.18 ($SD = 1.60$) respectively.

One-way ANOVAs showed no significant differences between the experimental conditions on post-test domain scores, understanding scores, relate scores and translate scores ($F(1,118) =.25$, $p = .62$; $F(1,118) = .74$, $p = .39$; $F(1,118) = .99$, $p = .32$; $F(1,118) = .16$, $p = .69$).

Discussion

Overall, we found that subjects learned from working with the learning environment; post-test scores on the domain and understanding items were significantly better than pre-test scores. In contrast with our expectations, no differences where found between experimental conditions. So, subjects learned equally well regardless of the way the representations were presented.

This leaves us with the question: Why did sequencing representations not support learners in relating and translating between representations? Do we have to adapt our theory? In search of an answer to these questions we analysed the log files to get insight in the way learners worked through the learning environments. The data suggest that an intervening variable played an important role: the instructional support consisting of assignments and explanations. The instructional support had a great impact on how learners worked with the learning environment. It was the same for both conditions, but was organised according to the steps in the experimental condition where we sequenced the representations. The assignments and explanations directed the subjects' attention to the newly introduced representations and variables. It looks like the instructions supported the subjects in the progression of the learning material; sequencing the material from simple to complex. Thus, it may have affected the subjects processing of the representations.

Although we tried to encourage the subjects to explore the simulation and reflect on their actions by asking them to prove their answers by experiments done and to provide an explanation for their given answers, the log files showed that learners did not explore the simulation for other features than explicitly indicated in the assignments and their reflections were very brief. In short, the instructions guided the subjects through the learning environment with little else being attended to. As a result, the subject did not focus on relating representations and translating between them. Therefore, the expected support from representational progression was not found in this study.

Despite of our attempt to engage the subjects in relating representations and translating between them, they do not seem to do so if they are not explicitly asked to. We believe the intervening effect of instructional support in the present study can help us to improve the effects of providing multiple representations in the future. In a follow-up study we are going to use the current results to adapt the instruction. Instead of focusing on domain knowledge in the instruction, we are going to try to encourage learners to relate and translate between representations by explicitly asking them to do that. We believe that sequencing the representations are of additional support here. They avoid overloading learners by directing their attention only to the representations they are asked to relate and translate between. Step-by-step learners are guided to relate more representations and translate between them.

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