A user experience case study: two embodied cognition user interface solutions for a math learning game

1. Introduction There is a great deal of evidence that understanding of fractions is very difficult for children and that even after considerable mathematics instruction many children fail to perform adequately even in simple fraction tasks. Mathematics education researchers have admitted that most of the students' difficulties with rational numbers can be attributed to inadequate instruction. The problem is that the recent advances in modelling numerical development have not been exploited to practices of teachers and the instruction tends to emphasize procedural instead of conceptual knowledge. Game based learning solutions provide possibilities to teach conceptual number knowledge in engaging way. Engagement is however not an automatic gain when mathematic learning is converted into a game. Optimization of user experience is important because the previous research have shown that subjective playing experience is positively connected with playing performance and learning outcomes. The enjoyment level that an educational game offers is a key factor in determining whether a player will be engaged in the gameplay and achieves the desired objectives of the game. In this paper we will first shortly present the theoretical background of the Semideus game following with a description of the game. Second, we will report the results of the user experience study in which the two user interfaces, both based on embedded embodied cognition, of the game were compared. Third, we will consider the further development of the game's user interface according to the results of this comparison study.

2. Game description The Semideus game is designed to support the development of rational number conceptual knowledge. In particular, the game addresses the development of two sub-concepts necessary for a complete mathematical understanding of rational numbers, 1) representations of the magnitudes of rational numbers and 2) the density of rational numbers. The idea of the game is grounded on integrated theory of numerical development while it steadily expands understanding of the connection between different number representations and their magnitudes. The understanding is gradually expanded from whole number magnitudes to magnitudes of fraction, decimal and percent numbers. The game supports five different kinds of tasks: magnitude estimation, magnitude comparison, magnitude ordering, and density awareness. In this study we focus on estimation and ordering tasks. All the tasks in the game are performed on a number line as the recent research has suggested that instructional interventions should target learners' interpretation of rational numbers as magnitudes by practicing them on number lines. Two different user interface solutions were developed for this study. Both user interfaces require some physical activities, but the intensity needed for controlling the game varies. In the first version the game the character is controlled on a number line by tilting the tablet device (light gestures). The second version requires walking still with the tablet and the direction of the game character is determined by tilting the tablet. The embedded embodied cognition approach assumes that seemingly abstract representations may be based on bodily experiences and movement may help children to understand abstract concepts better and the perceptual and interactive richness provides opportunities for alleviating cognitive load.

3. Method In the study, 45 Finnish university students played both versions of the game: tilting user interface and walking user interface. The playing order was randomized. After that they filled in a questionnaire. In the end 9 participants were dropped as they did not play both versions of the game or filled in the user experience questionnaire inadequately. Even though the targeted end users for the game are school pupils the participants were university students. This selection of participants was intentional as the students are more fluent with fraction number magnitudes. This way the findings from the study are more likely to be based on the game itself rather than players' mathematical skills. User experience was measured in terms of flow experience and playability. We selected flow theory as a game quality measure because flow seems to have a positive influence on performance enhancement, learning and engagement and flow has been
successfully used for analyzing the quality of serious games. Flow experience was measured with a 9-item questionnaire developed by the authors. The items included were derived from flow scale used in another study (Külli et al, 2014). The dimensions included were challenge-skill balance, clear goals, concentration, autotelic experience, loss of self-consciousness, sense of control and action awareness merging. Playability was measured with a 3-item questionnaire developed by the authors. The dimensions included were ease of use, intuitiveness of the user interface and controlling accuracy of the user interface. 4. Results and conclusions. The players experienced significantly higher flow with tilting user interface than with walking user interface. The biggest differences were in sense of control, action awareness merging, and autotelic flow dimensions. When comparing the estimation accuracy with combined values we can see that student estimated magnitudes more accurately with tilting based user interface than with walking based user interface, but the difference was not statistically significant. In general, the results clearly show that the tilting user interface was better with all used measures. Although, the difference in controlling accuracy (Percentage of Absolute Error) was not large between the tested user interfaces, players experienced the walking user interface more inaccurate than it actually was. If we could facilitate the sense of control and action awareness merging in walking user interface, it could facilitate a lot the overall user experience. Walking controls required more concentration from the participants and it influenced negatively on the playing experience from time to time. Based on the question concerning which controlling mode the participants preferred, it can also be seen that the tilting mode was preferred over the walking mode. It is also worth noting that, after playing the game for a while, most of the players of the walking version reverted to just shaking the device instead of walking still. The study showed that walking as a controlling method for Semideus game was problematic. It distracted players and caused them to feel less immersed in the game. At the same time however, the use of walking UI did not result in significantly worse answer accuracies. The tilting UI worked much better and the physical activity required to control the character felt natural. This would indicate that the physical controlling itself is not an issue if implemented properly. The limitations of the study should be considered. The sample size (45) is rather small and the actual number is even smaller (36) as not all of the participants finished the test. Also the participants were not of the targeted end users. Adults may feel differently about physically moving during the game than children do. The participants played each version of the game for about 20 minutes. This was probably enough to form an opinion about the controlling methods but still, longer sessions might reveal for example better familiarization or increased exhaustion that might affect the playing experience. Based on the findings of his study, the game has been slightly modified. Especially the walking UI has received some fine tuning. Another data gathering with the two refined UIs involving 6th graders has already been conducted for further studies.