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Evaluation of interactive on-screen videos for geometrical constructions in virtual space

How can students learn to solve problems in mathematics by using appropriate computer tools? Furthermore, how should these tools and supporting media be designed that especially people, who are not interested in mathematics, can be motivated to act in an individual, specific and effective way? Possibly with new constructive strategies, which enable interactive solving of problems, such as concept formations, calculations, finding sets, heuristics, proof strategies, constructions etc.

With appropriate computer tools for mathematical education like dynamic geometry systems, intelligent tutorial systems etc., students can get an individual approach to mathematics. Ingenious dynamic spatial geometry systems like Cabri 3D (BAINVILLE & LABORDE 2004 - 2007) allow the naïve user an interactive and intuitive approach to generate and manipulate spatial constructions without knowing the methods of descriptive geometry. As follows, our statements are limited to geometrical constructions in virtual space by using Cabri 3D (SCHUMANN 2007).

Videos (screen-recorded, real filmed, trick filmed, animated filmed etc.) can support the usage of these tools and build a bridge between tools and users. On the one hand, they can help, support, and unburden teachers while working with students; on the other hand they can lead students to an independent self-action. Beyond the pure mathematics and the mathematics education skills, the students should improve media literacy in the sense of critically handling the media, and achieve methodological competence.

Considering learn-, cognition- and instruction-psychological reflections, these kinds of videos belong to the learning by imitation and observation. They represent basics of learning processes (ATKINSON ET AL. 2000, BANDURA 1971; KLAUER & LEUTNER 2007).

A first pilot study with 165 fourteen-year-old German students showed, that there are statistically significant differences in mean values between various film modes regarding voice comments, text comments, different appearance of catchword cards, menu numbering and preview pictures concerning the instruction of spatial reconstructions. In a second pilot study with 242 students it could be shown, that there are statistically significant differences of preferences between these film modes (KNAPP & SCHUMANN 2007). The instructionally designed film mode with the statistically significant highest and most effective reconstruction results,

which was also preferred by the students, and other quantitative and qualitative research results of the pilot studies were used to create a design for interactive instructionally on-screen videos (IIVs).

So we characterize an IIV as a film, which enables the user in an individual step by step human-computer-interaction input-output schemata to study and emulate an expert's problem solution. We implemented a start-, pause-, stop-button, sliding controller, and catchword cards representing menus as basic interactive options to operate with the IIV. Of course, the user can use permutations of the above mentioned options.

According to the mentioned pilot studies, nine different types of worked-out solution procedures in worked-out examples were created as IIV. In particular, videos for spatial orientation, visualization, and rotation were created by using worked-out examples for exact construction, dynamic penetration, analogical formation, facetted solids, composition of solids, manipulative fit in exercise, solids´ net in an edge model of a cube, parallel projection and an orientated cone put on a sphere.

Methodology

The reproduction and comprehension achievements (KMK 2003: AFB 1 and 2) were investigated by appropriate measurements. Definitions of terms, applied measurements and the corresponding theoretical reflections were explained in the lecture.

The possible intervened variables of the students were limited to cognitive efficiency, anxiety, math self-assessment, computer experiences, each with its subvariables as well as special questions for each worked-out example.
The possible intervened variables of the different geometrical contents of the IIVs were examined such as available time (150 % of the film duration), mouse-pointer-length (absolute, per minute), words (absolute, per minute), clicks (left, right, long, short), used features within Cabri 3D to attain the construction goal etc.

The data were collected by questionnaires, software-based solution for human-computer-interaction according to ACM-usability-standard and from objective, valid, and reliable tests to apply qualitative and quantitative measurements for analyses.

For organisational reasons, the survey could only be carried out by intact groups (= school classes). As a classical statistical evaluation tool (BORTZ & DÖRING 2006), the analysis of covariance was chosen to compare mean values. 262 fourteen-year-old students of secondary schools in the south of Baden-Württemberg, Germany, took part in this study. To allow for possible intervened students variables, the students take different pre-tests

and measurements. After the pre-tests, every school class operated with one of the nine IIVs. While interacting, each student had to reconstruct the worked-out solution procedure of the worked-out example by using Cabri 3D.

Results and discussion

One IIV included a physical instruction by using keyboard keys. Analyses of variances and t-tests showed statistically significant differences in mean values. For that reason the IIV took not part in further analyses. We state the hypotheses that the IIVs are not able to instruct in an appropriate way above physical instructions.

Above all films and probands, the IIVs led to absolute means over 70% concerning reproduction achievements and over 50% concerning comprehension achievements compared with the experts´ solution. These results were gained even with the limited editing time.

Over all, IIVs reproduction and comprehension achievements correlated with $r = 0.345$.

One- and two-factorial-analyses of covariance and appropriate coefficients of correlation (Bravais-Pearson, rank-biserial etc.) showed statistically significant gender differences. Central tendencies were that boys attained higher reproduction and comprehension achievements than girls.

In one- and two-factorial- analyses of covariance concerning reproduction achievements boys got statistically significant higher differences in mean values of medium effect size (ROST 2005) than girls. The IIVs showed statistically significant differences in mean values of medium effect size.

In one- and two-factorial- analyses of covariance concerning comprehension achievements boys got statistically significant higher differences in mean values of small effect size than girls. The IIVs showed statistically significant differences in mean values of medium effect size.

The larger the tool-content based IIV mouse-pointer-length per minute was the minor were the reproduction and comprehension achievements. The analyses of content-tool based IIV like the absolute number of right or left clicks showed medium, the film duration and the clicked tools within Cabri 3D showed small influences to the reproduction and comprehension achievements.

There were content-tool and tool-content based differences, respectively between the examined IIVs. However, we state that for each IIV, its mathematical content and the used tools empiric studies had to be carried out to prove the didactical surplus value.

The students preferred the start-pause-buttons and start-pause-buttons together with the sliding controller permutations of interactive film options. However, no statistically significant differences could be found, but we have to bear in mind that several cells were undersized for a general statistical phrase.

Besides the gender, the mental rotation ability, playing 3D computer games and the feeling of being pressed for time showed statistically significant influences of medium effect size for reproduction achievements. With regard to comprehension achievements the reasoning showed an influence of medium effect size.

The examined students liked to operate and handle with IIVs, were very concentrated, and were positively touched.

IIVs with worked-out solution procedures in worked-out examples can yield in fast and effective learning. The success depends on special abilities like mental rotation and reasoning.

Referring to the extern and intern validity of the studies, IIVs contain a huge potential at least for teaching and learning of spatial geometry in schools. Different quantitative and qualitative analyses showed, that IIVs can help students to learn individually, get the feeling of success, become motivated, learn to reproduce and understand mathematical contents (here spatial dynamic geometrical constructions) and work very concentrated. Empirical studies of the implementation of IIVs in interactive learning environments ("tutorials") still don't exist and are urgently needed.

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