Effectieve kenmerken van een digitaal biologie practicum in het hoger onderwijs
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Summary

The research at hand has examined which instructional characteristics of the digital practical course ‘Regulation of cardiac activity’ contribute to the success of this practical course in terms of effectiveness and efficiency. Objective for the students of the practical course is to obtain insight in the theory according to the scientific method. The practical course about the regulation of the cardiac muscles of the frog has been designed by the department Animal Physiology, part of Biology in the University of Groningen. In 1975 this practical course has been introduced in the first year Biology curriculum and in the second year Pharmacy curriculum. The students had to carry out the experiments on a living frog. After experimenting the students wrote a scientific report which was assessed. As a result of student protests against mandatory use of animals in scientific education a video covering the preparation of the test animal, the test equipment and the experiments was completed with financial support from the Dutch Ministry of Education. In 1985, this new instructional method (linear video) has been introduced. The students went through the video in a group instead of experimenting themselves. Afterwards they wrote their scientific report at home. In 1987, the education board of Biology decided that reporting no longer should be part of the Animal Physiology course, because of a too large study load for students. For the Department of animal physiology this decision was a reason to design a computer-based alternative of the course using the earlier developed video.

The first version of this computer-based practical course was introduced in the Biology curriculum in 1988. The version exists from a learning environment in which the animal experiments are offered and an assessment environment in which the essays are written. The scientific problem treats the question how the regulation of the cardiac muscles functions and has been subdivided in four problems areas. The problems had been gone through in a fixed order. The structure of a problem exists from presenting the problem, choosing a suitable experiment, carrying out the experiment by means of watching the video and solving the problem by means of the online writing of a short essay. Experiments are offered in the form of a tutorial. Two problems are preceded by activation of prior knowledge. During the first problem the preparation of the test animal has been shown and the test equipment has been introduced. Extra help is available in the form of a glossary, information about necessary prior knowledge and a test about prior knowledge. The problems are preceded by an introduction, in which the scientific problem is described and the structure of the practical course is explained. After finishing the computer-based practical course the four short essays have been assessed (grade on the practical course).
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Because of technical innovations four new versions of the computer-based practical course have been introduced since the first version (Beetsma, 2004a). Introducing these new versions has been successful in terms of efficiency.

With the same learning result (effectiveness) both for students and teachers a reduction in time (efficiency) has taken place. Students spent twelve hours on the first version of the practical course (live animal experiments). This time has decreased up to an hour and a half on the last version of the computer-based practical course. Teachers spent 150 hours on an annual basis on the first version of the practical course (live animal experiments) for assisting in the laboratory and assessing the essays. This time has decreased up to five hours for assessing the essays on the last version of the computer-based practical course.

The basis of the research consists of time logs of students passing through the versions of the computer-based practical course. All kinds of disturbing factors influenced the core variables grade on the practical course, student time to the practical course and prior knowledge of the student. For this reason only the logfiles of one version of the computer-based practical course and one educational situation have been involved in this research in order to create a situation as homogeneous as possible. The data in the logfiles, collected at display level, have been encoded and aggregated. An education effectiveness model of the computer-based practical course has been used as a guiding principle. This model has been inferred of the education effectiveness model for class education of Creemers (1994) and exists on the instruction level from the components quality of instruction, opportunity to learn and time for learning and design restrictions.

To define effective factors in the component ‘opportunity to learn’ principles of mastery-learning according to Bloom (1974) have been used. To define effective and efficient factors in the component ‘quality of instruction’ the nine instructional events van Gagné (1970) have been used. The choice of the instructional factors has been based on information processing theory, on mastery-learning and on constructivism. The component ‘time for learning’ exists from the factor cooperation, because cooperation has been used in case of failing equipment.

At student level the components ‘learning behavior in the learning environment and assessment environment’, the ‘dynamic part of motivation’ and ‘student background factors’ have been distinguished. In the model the component motivation takes a core and controlling position. The component ‘learning behavior in the learning environment’ of the course exists from time spent on new instruction in the problems. The component ‘learning behavior in the assessment environment’ exists from time spent on writing essays. Achievement in the short term exists from the grade on the practical course and achievement in the long term exists from the grade on the theory test. Student background factors exist from prior knowledge at the start of the study, prior knowledge during the study, gender, language skill and courseware literacy.
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Research questions and hypotheses have been formulated about relations between the components on instruction level, the component motivation and learning behavior in terms of time on task and achievement. The hypotheses about the influence of instructional factors on achievement and time on task have been based on the one hand on the concept Academic learning Time, introduced by Fisher et al. (1980) and on the other hand on the concept that time on task is a reflection of learning in terms of underlying cognitive processes (Sternberg, 1969; Caffee, 1976; Gagné, 1970; Hannafin & Peck, 1988; Wager & Gagné, 1988). The hypotheses about the influence of design restrictions and cooperation have been based on the less motivational effect design restrictions could have (Clark & Sugrue, 1990). These design restrictions, cooperation and student background variables have been incorporated as covariates in the model, because former research shows that prior knowledge of the student has a strong influence on achievement (Dochy et al., 1999; Reynolds & Walberg, 1991, 1992a, 1992b, 1992c) and on time on task (Gettinger & White, 1979; Gettinger, 1984a). The data have been analyzed using descriptive statistics and using stepwise regression analyses and commonality analysis which exists from the additive, unique and shared contribution to explained variance in the dependent variables. The dependent variables are time spent on new mandatory instruction offered in the problems, time on writing essays, grade on the practical course and grade on the theory test.

The average achievement level is high: the grade on the practical course amounts to 7.53. Students spent on average one hour and a half in the practical course. A very large part of time spent in the practical course is time on task: in the learning environment time on task amounts to 91 percent and in the assessment environment time on task amounts to 100 percent. Students spent five and forty percents of the total time on mandatory materials of which almost half to going through new instruction in the problems, ten percents to extra materials and five percent to design restrictions in the learning environment. Students spent forty percent of the total time on writing essays. On writing the first essay the lowest time is spent (almost six percent) and on the remaining essays round ten percents.

The predicting value of factors in the practical course to grade on the practical course (achievement in the short term) is large and amounts to thirty percents. Factors in the learning environment explain ten per cent of the total variance in grade on the practical course and factors in the assessment environment explain twenty percents. The predicting value of the factors in the practical course to time spent on new instruction in the problems and to time spent on writing essays is large: instructional factors explain more than forty per cent of the variance in new instruction in the problems and thirty percents in writing essays in the assessment environment. The predicting value of factors in the practical course on grade on the theory test (achievement in the long term) is small, namely six percents.
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The findings indicate that time spent on the introduction in the learning environment and the length of the essay in the assessment environment influence grade on the practical course positively.

In addition, the application of the principles of mastery-learning according to Bloom (1974) is effective. Both the learning environment and the assessment environment have been designed in such a way that the student gets the opportunity to spend time he or she needs to reach the desired level of mastery. However, the student is selective in the way to which components to spend time. In the learning environment the student decides to spend time only to the new mandatory materials. The student hardly spends time to the extra offered materials in the learning environment. Studying these extra materials does not lead to a higher grade on the practical course with exception of studying the introduction. The assessment environment has been designed in such a way that the student in the first three essays works in his or her own pace and way. Only the contents of the last essay influence the grade of the practical course positively. Apparently, the practical course gives the students the opportunity to learn without punishment. The student is, however, selective in the way spending time on writing essays. In the second essay the student spends much time at writing, what leads up to many words and a better grade on the practical course. The contents of the second essay can be considered as preparation to the last essay.

In addition, the practical course contains very few design restrictions. As a result the student loses hardly time and does not lose motivation, with one exception. Students who are confronted with a mistake in the software spend less in writing essays. However, this confrontation does not lead to a lower grade on the practical course.

The findings with respect to effectiveness and efficiency indicate that the results only apply to achievement in short term. Only one variable has predictive value on the grade on the theory test (achievement in long term), but this variable can be interpreted as behavior of a ‘good student’.

At designing the computer-based practical course the instructional events according to Gagné have been taken as guiding principles (van Gulik & Metz, 1989). The instructional events exist from providing opportunities for orientation, activating prior knowledge, presenting instruction, guiding the learning, checking the level of comprehension, providing feedback, assessing performance and enhancing retention and learning transfer. The instructional events refer to underlying cognitive processes.

At the design of presenting instruction an authentic environment has been created by using simulations of the reality and by using multimedia. The scientific method has been simulated by a video of the animal experiments, the preparation of the test animal and the test equipment. The scientific reporting has been simulated by online writing short essays. At the design of the last four instructional events effectively proven principles of mastery-learning have been applied, namely use of
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formative and summative tests, strive for a fair assessment of given answers, giving feedback and corrective instruction.

Comparison of other courseware which has been developed by the author of the research on hand indicates that beside the application of the nine instructional events according to Gagné (1970) especially the instructional factors 'presence of formative and summative tests' and 'full screen, full motion video' have been determinative for the success of this practical course (Beetsma, 2003).

The research at hand has produced an education effectiveness model for courseware, derived from the education effectiveness model of Creemers (1994) for class education. At the definition of the instruction level results of studies into effective and efficient instruction factors of courseware are applied and results from three approaches in instructional theory. This model has been used as a guiding principle at structuring and analyzing collected time logs. The developed model can also be used as a guiding principle at evaluating and developing courseware. Moreover, the model offers the opportunity of getting insight in underlying cognitive processes of learning.