PROO

Aanvraagformulier subsidie voor afzonderlijke projecten
2002/2003
Programmaraad Onderwijsonderzoek
(Gebied Maatschappij- en Gedragswetenschappen)

Dossiernummer: 411-02-107-V

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ICO

overige aanvrager(s)

namen, titels/ universiteit, vakgroep/
onderzoeksschool:
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Universiteit Nederland, OTEC

1b. Recente publicaties en andere gegevens uit past performance hoofdaanvrager

<table>
<thead>
<tr>
<th>AUTEURS</th>
<th>TITEL</th>
<th>TIJDENSCHRIFT</th>
<th>JAAR, NR</th>
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<tr>
<td>Van Merriënboer, J., Kirschner, P., &amp; Kester, L.</td>
<td>Taking the load off a learner’s mind: Instructional design for complex learning</td>
<td>Educational Psychologist</td>
<td>in press</td>
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AWARDS


Training Magazine 2000 – Featured as one of the world’s thought leaders in the field of Educational Technology.
2. Titel van het onderzoeksproject

Personalized competency-based education through the dynamic selection of learning tasks in electronic learning environments

Nederlands:
Gepersonaliseerd competentiegericht onderwijs middels de dynamische selectie van leertaken in elektronische leeromgevingen

3. Korte samenvatting van de probleemstelling

Competency-based education is characterized by the fact that rich learning tasks, which are more or less representative for later professional tasks, form the backbone of a curriculum. All other parts of the curriculum (lectures, practicals, skills training etc.) are connected to this backbone. Thus, competencies are not coupled to separate courses or modules but developed throughout the curriculum. In addition, a flexible curriculum should make it possible to take elsewhere-acquired competencies into account. Taken together, these characteristics of a competency-based curriculum indicate that for each individual student with a particular learner profile at a particular moment in time, it should be possible to select suitable or necessary learning tasks, to emphasize or de-emphasize particular aspects of those learning tasks, and to exclude other learning tasks. The main goal of the proposed project is to develop an effective model for personalized task selection in a competency-based, electronic learning environment in secondary vocational education. This includes the specification of a learner profile, a dynamic task selection model, and assessments for updating the learner profile. Three experiments will study (1) effects on student satisfaction and learning outcomes of giving students—limited—control over learning task selection, (2) transfer effects of increased variability in a set of selected learning tasks, and (3) differential transfer effects of increased variability in example materials ("presentation variability") and increased variability in required problem solving behavior ("practice variability"). The dynamic task selection models developed and validated in this project make it possible to select appropriate learning tasks for students, increase the flexibility of education, and can be directly implemented in electronic learning environments.

4. Publicaties
in welke vorm zullen de resultaten van dit project worden gepubliceerd?

Dissertation, three articles in scientific journals.

5. Periode aangevraagde subsidie

duur (jaren): 4
startdatum: September 2003

6. Onderzoeksterrein (raadpleeg de toelichting)
onderzoeksgebied volgens de indeling Trefwoorden Expertise Onderwijsonderzoek

12500, 12800, 13030

7. Samenstelling van de onderzoeksgroep

<table>
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8. Hernieuwde aanvraag
   □ nee
   □ ja  vorige jaar/jaren:  vorige kwalificatie:

9. Plaats van uitvoering
   organisatie:  Open Universiteit Nederland
   instituut:  Onderwijs-technologisch Expertisecentrum (OTEC)
   adres:  Postbus 2960
   postcode:  6401 DL  plaats: Heerlen

10. Is de aanvraag ook elders ingediend?
    □ nee
    □ ja, bij:

11. Financiële bijdrage aan het project door derden (wat, hoeveel en door wie):
    Geen.

Gelieve de antwoorden op vraag 12 en 13 aan het formulier te hechten
(bij de antwoorden geldt voor de vragen 12 en 13 samen een maximum aantal van 4200 woorden; raadpleeg
de toelichting). U wordt verzocht het aantal woorden van de beantwoording van deze twee vragen aan het eind van de
invulling van vraag 13 te vermelden. Aanvragen die dit maximum van 4200 woorden overschrijden worden niet in
behandeling genomen.

12. Beschrijving van het project
   Raadpleeg u voor het invullen van vooral ook dit onderdeel de toelichting
   12.1 wetenschappelijk belang
   12.2 uitwerking van probleemstelling
   12.3 methodisch-technische opzet
   12.4 relevantie
   12.5 literatuuropgave
   12.6 belang en plaats van het project in het PROO-programma
   12.7 internationale oriëntatie

13. Onderzoeksplan
   Raadpleeg u voor het invullen van vooral ook dit onderdeel de toelichting.
   13.1 gedetailleerde beschrijving van het onderzoeksplan voor de eerste twaalf maanden
   13.2 globale uitwerking van het onderzoeksplan voor de resterende duur van het project
   13.3 disseminiatieplan

Hoofdaanvrager: Prof. dr. Jeroen J.G. van Merriënboer  Plaats: Heerlen

Handtekening:  datum: 30 september 2002

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12 DESCRIPTION OF THE PROJECT

12.1 Scientific relevance

12.1.1. Towards Personalized Competency-based Education
Recent instructional theories tend to focus on authentic learning tasks that are based on real-life tasks as the driving force for learning (Reigeluth, 1999a; van Merriënboer & Kirschner, 2001). The general assumption is that such tasks help learners to integrate the knowledge, skills and attitudes necessary for effective task performance; give them the opportunity to learn to coordinate constituent skills that make up complex task performance, and eventually enable them to transfer what is learned to their daily life or work settings. This focus on authentic, whole tasks can be found in several educational approaches, such as the case method, project-based education, problem-based learning, and competency-based education. Van Merriënboer’s four-component instructional design model (4C/ID-model, 1997; van Merriënboer, Clark & de Croock, 2002; Janssen & van Merriënboer, 2002) describes how learning tasks fulfil the role of a backbone for an integrated curriculum (Figure 1: the “circles” represent learning tasks). Three requirements for this backbone are: (1) learning tasks are organized in simple-to-complex task classes, (2) learners receive guidance for the first learning task in a task class after which support slowly disappears, and (3) learning tasks within the same task class show a high variability. Each of the three requirements will be briefly discussed below.

Figure 1. A sequence of learning tasks, organized in task classes and with fading support in each task class. Learning tasks within the same task class show a high variability on dimensions that also vary in the real world.

First, it is clearly impossible to use highly complex learning tasks right from the start of a curriculum because this would yield excessive cognitive load for the learners, with negative effects on learning, performance and motivation (Sweller, van Merriënboer, & Paas, 1998; van Merriënboer, Kirschner, & Kester, in press). The common solution is to let learners start their work on relatively simple learning tasks and progress towards more complex tasks. In a whole-task approach, the coordination and integration of constituent skills is stressed from the very beginning, so that learners quickly develop a holistic vision of the whole task that is gradually embellished during the training. This is akin to the “global before local skills” principle in cognitive apprenticeship (Collins, Brown, & Newman, 1989, p. 485) or the “zoom lens metaphor” of Reigeluth’s elaboration theory (1999b). There are categories of learning tasks or task classes, each representing a version of the task with a particular complexity (the dotted boxes in Figure 1). Learning tasks within a particular task class are equivalent in the sense that the tasks can be performed on the basis of the same body of generalized knowledge. A more complex task class requires more knowledge or more embellished knowledge for effective performance than the preceding, simpler task classes. In other words, each new task class contains learning tasks that are in the zone of proximal development of the learners (Vygotsky, 1934/1987).

Second, when learners start to work on a new, more complex task class, it is essential to give them guidance and support. This support diminishes in a process of “scaffolding” as learners acquire more expertise (see the filling of the circles in Figure 1). One powerful approach to scaffolding is known as the “completion strategy”. In this strategy, learners start to work on case studies that confront them not only with a given problem state and a desired goal state, but also with an example solution. Questions and evaluation assignments stimulate the learners to reflect on the strong and weak points of the given solution. Studying case studies focuses the learners’ attention on problem states and associated solution steps and so enables them to induce generalized solutions or schemata. Then, learners may proceed to work on completion tasks that present a given state, a goal state, and a partial solution that must be completed. There is still a sizeable support, because the given part of the solution provides direction to the problem solving process. Finally, learners receive conventional tasks without support – only then, they have to construct complete solutions. Several studies showed positive effects on learning for the completion strategy (Renkl, Maier, Atkinson & Staley, in press; Stark, 1999; van Merriënboer & de Croock, 1992).
Third, it is essential that learning tasks within the same task class show a high variability, that is, differ from each other in terms of the saliency of defining characteristics, the context in which the task has to be performed, the familiarity of the task, or any other task dimensions that also vary in the real world (Paas & van Merriënboer, 1994). Note that the learning tasks within a particular task class are equivalent in the sense that the tasks can be performed on the basis of the same body of generalized knowledge. Variability is the key factor for reaching the necessary level of generality and facilitating transfer of learning to daily life or future work setting.

In a flexible curriculum, it should be possible to take differences between students into account. Some students are better able to acquire new competencies and need therefore less practice and support than other students. In addition, elsewhere-acquired competencies of new students should be taken into account. And competencies are not coupled to separate courses or modules but developed throughout the curriculum, which makes it even more important to be able to select suitable learning tasks for students at any given point in time. In the framework sketched above, this means that for each individual student, it should be possible to select the best task class to work on and to select a learning task with the optimal level of support within this task class. Furthermore, this task should be selected in such a way that variability of all tasks within the same task class is guaranteed. Electronic learning environments allow for such personalization of instruction.

12.1.1. Dynamic Learning Task Selection
Models for dynamic task selection have mainly been developed for use in Intelligent Tutoring Systems (ITS). For instance, van Merriënboer and Luursem (1996; van Merriënboer, Luursem, Kingma, Houweling & de Vries, 1995) developed a task selection model for CASCO (a loose acronym for Completion ASSignment CONstructor), an ITS for teaching computer programming. The task selection model bases its decisions on a learner profile, which is continuously updated with information on the learner's progress. Learning tasks that are suitable for presentation to the learner are selected “on the spot” from an existing database with tasks. Selection rules include: (a) the learning task must not be too difficult for the learner (i.e., not require too many competencies that are not yet introduced or not yet mastered at the required level), (b) the learning task must offer the opportunity to remediate competencies that the learner makes mistakes with, (c) the learning task must offer the opportunity to further practice competencies that are not yet performed at the required level, and so forth. The CASCO task selection model used fuzzy logic to make the selection process as robust as possible and to yield a prioritized list of learning tasks. An advantage of this approach is that a shortlist of suitable learning tasks can be presented to the learner, after which the learner makes a final selection. There are indications that this—limited—learner control may have positive effects on learner’s motivation.

Another important issue for task selection is related to variability. The general idea is that a newly selected learning task must differ on a number of relevant dimensions from previously presented learning tasks to ensure a high variability in the task class, e.g., require (some) other competencies than previous tasks, present the task in another fashion, or place the task in another context (Camp, Paas, Rikers & van Merriënboer, 2001; de Croock, van Merriënboer, & Paas, 1998). This principle can be applied in a straightforward way when only one type of learning tasks is used. For instance, when case studies are selected from a database with learning tasks, one may ensure that each selected case study is sufficiently different from previously selected case studies on a number of relevant dimensions. However, van Merriënboer, Schuurman, de Croock and Paas (2002) describe a complication when different types of learning tasks are used – as is done in the completion strategy (i.e., first case studies, then completion tasks, and finally conventional tasks). Contrary to their expectations, a high-variability sequence of completion tasks did not yield higher transfer performance than a low-variability sequence of completion tasks. A possible explanation is related to the nature of completion tasks, which integrate the presentation or illustration of new competencies (in the given part of the solution) and the practice of competencies that have already been introduced (for the to-be-completed part of the solution). In their study, variability only referred to variability in the given parts of the solution. But closer inspection showed that low-variability tasks actually required the learners to combine many competencies to complete the solution (i.e., practice variability is high) and, vice versa, high-variability tasks required them to combine few competencies to complete the solution (i.e.,
practice variability is low). The point is that it may be necessary to include both presentation variability and practice variability in a task selection model.

12.1.3 Research Question
The overall research question is: What does an effective model for personalized task selection in a competency-based, electronic learning environment look like? More specific questions are:
- Should an effective task selection model select and present one task (system control) or select a number of suitable tasks and let the learner select from this shortlist (limited learner control)?
- Should an effective task selection model for case studies include special selection rules that ensure a high-variability sequence of cases, in order to reach transfer of learning?
- Should an effective task selection model for a scaffolded sequence of learning tasks (e.g., from case studies to conventional tasks) include distinct selection rules for “presentation variability” and “practice variability”?

12.2 Elaboration of the research question

Experiment 1: Personalization and control over selection
For this experiment, a learner profile, a task selection model, and assessments for updating the learner profile will be developed. The learner profile will be based on a competency profile and use fuzzy sets to model competency development (cf., van Merriënboer & Luursem a, 1996). The task selection model selects the optimal task class, determines the appropriate level of task support, and prioritizes learning tasks from very suitable to not suitable. Assessments for updating the learner profile are performance-based; tasks without support (i.e., the circles without filling in Figure 1) are used as test tasks. The task selection model will be tested in a factorial experiment with two factors: Personalization (personalized selection based on a learner profile vs. yoked control) and Selection control (system control vs. limited learner control). The factor Personalization is used to test if the selection of learning tasks on the basis of an individual learner profile is indeed more effective than non-personalized instruction. Each student will be paired to a "yoked control" student who receives identical learning tasks (not based on his/her own learner profile but on the learner profile of the peer!). The factor Selection control is used to test the added value of giving students—limited—control over task selection. For system control, one task is selected by the system and presented to the student; for limited learner control, a shortlist of tasks is selected (e.g., 3-5) and the learner may select one task from this shortlist. Best results are predicted for Personalized learning task selection with limited learner control.

Experiment 2: Variability and selection of case studies
Experiment 2 will take the most promising task selection model from Experiment 1 as a starting point. According to our hypothesis, this is the personalized model with limited learner control. This task selection model will be enriched with selection rules that ensure a preset level of variability of the learning tasks (thus, it selects a task that best fits the learner profile and yields a desired level of variability). For instance, selection rules may be included stating that a newly selected learning task must make an appeal to competencies not appealed to before, or must have particular values on dimensions that did not have those values before (e.g., values for the dimension context may be industry, government, service organization, education etc). Three versions of the task selection model will be implemented and compared: (1) a maximum variability model, which maximizes the differences between a selected learning task and previous learning tasks, (2) a minimum variability model, which minimizes the differences between a selected learning task and previous learning tasks, and (3) an intermediate variability model. The models are used to select learning tasks from a database with case studies only (i.e., maximum support). For the high variability model, highest transfer test performance is predicted because the variability promotes the construction of general, abstract knowledge that is most suitable to solve new problems. However, for this condition also longer training times and a higher investment of effort by the learners are expected (this pattern of results is known as the "transfer paradox", van Merriënboer, de Croock, & Jelsma, 1997).
Experiment 3: Variability and the completion strategy

This experiment aims at a further refinement of the task selection model, so that it can be used for a scaffolded sequence of learning tasks, in particular, the completion strategy that works from case studies, via completion tasks, towards conventional tasks. A distinction can be made between presentation variability and practice variability. For case studies, only the presentation variability is of importance and for conventional problems, only the practice variability is of importance. But for completion tasks, both types of variability are expected to interact with each other. A possible factorial experiment implements four versions of the task selection model and studies the factors Presentation variability (minimum, maximum) and Practice variability (minimum, maximum). However, the precise design of this experiment will also be based on the findings from Experiments 1 and 2.

12.3 Method

12.3.1 Domain and learning environment

The experiment will be conducted in secondary vocational education (“MBO”), in a technical domain. The research group has experience with the domains of process control, CNC programming, statistics and computer programming. Students will work on a relatively small number of learning tasks (e.g., five to eight) that each take not more than a half day to complete. The learning tasks will be selected from a ready-made database with about 50 tasks – based on our experiences with CASCO this is enough to guarantee sufficient differences between conditions.

The task selection models will be implemented in an electronic learning environment. This learning environment contains learner profiles and offers facilities for performance assessment, in order to update the learner profiles and then select a subsequent learning task for each individual student. However, this is not to say that no other media can be used. The electronic learning environment drives the work on the learning tasks, but—parts of the task—can be performed in another environment, students may attend lectures and study books to gather the necessary theoretical knowledge, or they may practice necessary procedural skills in a real-life setting.

Depending on the condition, different task selection models are employed in the electronic learning environment. In Experiment 1, the task selection models differ in system/learner control (system selects learning task vs. system selects shortlist and the learner makes final selection). Furthermore, the task selection model is used for some of the students (personalized instruction) but not for other students (yoked controls – i.e., coupled to the task selection model of their peer). In Experiment 2, the task selection models differ with regard to the amount of variability that is commanded by the sequence of presented learning tasks (minimum, intermediate or maximum variability). Finally, in Experiment 3, the task selection models differ with regard to the amount of “presentation variability” and “practice variability” that they realize in the sequence of selected learning tasks. Apart from the implemented task selection models, the electronic learning environments are identical to each other.

12.3.2 Measurements

Several control measures will be taken before and after the experimental treatments, including a prior knowledge test and an evaluation questionnaire concerning student’s perception of the learning environment. Furthermore, all the system and learner actions will be logged, so that learner profile states, selected task sequences, time-on-task and user actions can be observed from the logfiles. The main dependent measures are learning outcomes and cognitive load associated with the learning tasks.

Learning outcomes. The main learning outcomes are the rate of competency development during practice and transfer performance. The rate of competency development is derived from the changing states of the learner profile. After each learning task that was presented without support, performance measurements in terms of speed, endurance, accuracy, quality of product, and/or quality of process will be taken where relevant (depending on the selected domains for the experiments). These measures are then used to update the competency level for each competency that the learner practiced in that learning task. In this way it will be possible to register the development of a competency from the first time the student has to practice it.

Transfer performance is assessed by taking performance measurements on several transfer test problems. Transfer test problems confront students with problems that, compared to the practice tasks, have new properties or requirements that the student has to take into account. These kinds of properties or requirements are similar to those that are used to generate a sequence of learning tasks.
with high variability (in this sense, each next learning task in a sequence of learning tasks with high variability is a transfer task). For all experimental conditions the learning environment will select learning tasks from the database that have new properties that were not introduced during practice to serve as transfer test problems. However, these transfer problems will not require the application of new competencies.

In addition, there will be several measurements to estimate acquired conceptual knowledge. Depending on the selected domain suitable measurements techniques will be chosen to assess the quality of the acquired conceptual knowledge (e.g., test tasks in which the students have to explicate the advantages/disadvantages of different solutions for different problems, or card sorting tasks).

**Cognitive load.** Cognitive load will be measured after the students finished working on each learning task and test task. It is measured by a 9-point rating scale originally developed and validated by Paas and van Merriënboer (1994) and now widely used in cognitive load research.

### 12.3.3 Experiments

All experiments are characterized by the use of a fully randomized factorial design. There will be at least 20-24 participants per cell. For all experiments the dependent variables are competency development, transfer performance, conceptual knowledge, and cognitive load. All data will be analyzed with ANOVAs in combination with post-hoc tests.

**Experiment 1.** In this experiment in a 2x2 factorial design the effects of Personalization (personalized on the basis of learner profile vs. non-personalized yoked control) and Selection control (system control vs. limited learner control) will be studied. Before the start of the experiment, participants receive a prior knowledge test. Then the dynamically selected case studies or learning tasks are presented on the computer (e.g., two tasks per week). Participants work on those tasks in their own pace and may consult additional learning resources. After their work on the learning tasks, participants receive a transfer test, conceptual knowledge test, and evaluation questionnaires. Cognitive load is measured for all case studies/learning tasks and test tasks. The whole experimental procedure will take about 4 weeks.

**Experiment 2 and 3.** For experiments 2 and 3 the experimental procedure, tests and materials of Experiment 1 are used and, where necessary, adapted. Experiment 2 investigates the effects of high, intermediate and low variability. Differences in training times are expected but not corrected for, because they are an inherit consequence of the experimental treatments. Experiment 3 studies the effects of task selection rules for presentation variability and practice variability in combination with the completion strategy. The exact design of this experiment will be determined after Experiments 1 and 2 have been completed.

### 12.4 Relevance

The proposed project nicely fits three important developments in the field of education: (1) a movement towards educational systems in which rich learning tasks are the backbone of the curriculum, (2) an attempt to personalize education and improve its flexibility, and (3) an increased use of electronic learning environments. The dynamic task selection models developed and validated in this project are of direct relevance to these developments: They make it possible to select appropriate learning tasks for individual students, increase the flexibility of education, and can be directly implemented in electronic learning environments.

### 12.5 References


12.6 Relevance and place of the project in the PROO programme

This project fits the themes "ICT and Education" and "Vocational education", in particular the focus points “learner characteristics and competency development” and “organisation of learning trajectories”.

12.7 International orientation

There is close cooperation with the research groups of prof. Clark (University of Southern California), prof. Sweller (University of New South Wales) and prof. Merrill (Utah State University).
13. **ONDERZOEKSPLAN**

### 13.1 gedetailleerde beschrijving van het onderzoeksplan voor de eerste twaalf maanden:

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<tr>
<td>April – June 2004</td>
<td>Pilot studies.</td>
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<tr>
<td>July – August 2004</td>
<td>Revision of instruments and materials; final preparations for Experiment 1.</td>
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### 13.2 globale uitwerking van het onderzoeksplan voor de resterende duur van het project

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</tr>
<tr>
<td>December 2004-February 2005</td>
<td>Data analyses for Experiment 1 and writing the first article.</td>
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<td>March 2005 – February 2006</td>
<td>Experiment 2: preparation, data collection, data analysis, documentation, and publication.</td>
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<td>March 2006 – February 2007</td>
<td>Same for Experiment 3.</td>
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<td>March 2007 – August 2007</td>
<td>Completing the dissertation.</td>
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### 13.3 disseminatieplan

The findings will be presented at the international conferences EARLI, AERA and AECT. Each experiment is published in a separate article in an ICO-accepted journal.

*<Parts 12 and 13 together count 4188 words>*