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Effects of Web-based Support for the Construction of Competence Maps[1]

Angela Stoof, Rob L. Martens, and Jeroen J. G. van Merriënboer

Open University of the Netherlands

Correspondence concerning this article should be addressed to Angela Stoof, Open University of the Netherlands, Educational Technology Expertise Center, P.O. Box 2960, 6401 DL, Heerlen, The Netherlands. Telephone: +31 45 5762436. Fax: +31 45 5762802. E-mail: angela.stoof@ou.nl

Key words

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Abstract

Educationalists experience difficulties with the construction of competence maps that describe final attainment levels of educational programs. Web-based support was developed with three supportive aids: A construction kit, a phenomenarium, and an information bank. Each supportive aid was expected to improve perceived process and product quality as well as learning. In a factorial experiment, 266 educational science students constructed a competence map, whether or not supported by each of the three supportive aids. The availability of the construction kit and the phenomenarium had positive effects on perceived process quality and learning. Furthermore, if there was no phenomenarium with example materials, the absence of the construction kit greatly diminished experienced support (i.e., one aspect of process quality); if a phenomenarium was present, the availability of the construction kit had relatively little effect on perceived support. In general, this study indicates that well-designed Web-based support helps to construct competence maps.

The construction of a competence map is a difficult design process. The goal of the present study is to test if a Web-based support system may help designers to construct a competence map. In particular, the perceived effects of a construction kit, a phenomenarium, and an information bank on the quality of the construction process and the product of this process (i.e., the map) as well as on learning about the construction of competence maps were studied. In the Web-based support system, the construction kit consists of pre-fabricated parts and processes; the phenomenarium provides useful examples, and the information bank presents explicit information and guidelines.

A competence map is one of the core documents in competence-based education. In this type of education, which is regularly adopted in for example the USA, the UK and Australia, students do not acquire knowledge and skills but competencies instead. Here, competence maps describe the final attainment levels of an educational program in terms of interrelated competencies and subcompetencies (Schlusmans, Slotman, Nagtegaal, & Kinkhorst, 1999).

Earlier research has shown that the construction of a competence map is characterized by conceptual and procedural bottlenecks (Stoof, Martens, van Merriënboer, & Bastiaens, 2002; Stoof Martens, & van Merriënboer, 2004). Conceptual bottlenecks mainly pertain to difficulties designers experience with defining and demarcating the concept of competence and related terms such as knowledge, skills, expertise and ability. Procedural bottlenecks mainly pertain to difficulties with describing competencies and ordering them into a clear framework; unfortunately, there are yet no unequivocal procedures or supportive tools that help designers with determining and describing curriculum content in terms of competencies (van Merriënboer & Martens, 2002). This is a substantial problem, because a competence map is the main foundation for the development of a competence-based curriculum (de Bie, 2003). A possible solution is to provide teachers, educational managers and professionals who construct competence maps with a *task manager*, that is, a supportive tool showing which things to do when, by setting tasks to be undertaken, guiding users in executing those steps, and providing feedback on the quality of the process and the product.

A task manager can be combined with a construction kit, a phenomenarium and an information bank (Perkins, 1992). A *construction kit* consists of prefabricated parts and processes that are specifically designed for executing a particular task. Essentially, a construction kit takes over some routine aspects of performing this task. The most important considerations and theoretical notions have been incorporated in the construction kit, so that users do not have do deal with these issues themselves. For example, a construction kit leads the user through a prefabricated decision process, resulting in a personal standpoint, a particular presentation format, or another kind of product. The “wizards” that are included in many Microsoft applications are examples of a construction kit. After asking a few questions, they generate a document or other type of file that is specifically adapted to the users’ needs. A *phenomenarium* contains extractions, simplifications, simulations or models of the real world. It provides analogies that can be used for problem solving and decision making in performing a task. In its simplest form, a phenomenarium provides plain examples such as video recordings of presentation skills. More sophisticated phenomenaria may be interactive environments that can be manipulated by the learners, such as computer-based training programs on air traffic control. Finally, an *information bank* provides explicit information about several topics. It explains phenomena, names causes, gives background information, provides guidelines for performing particular tasks, and so forth. Straightforward examples of information banks are dictionaries and encyclopaedias. Examples that are specifically related to task performance are checklists, job aids and on-line help systems in computer applications.

The central research questions of this article are: (1) Do a construction kit, phenomenarium, and information bank improve the process quality of making a competence map? (2) Do they improve the quality of the products that result from this process? (3) Do they have a positive effect on learning to construct competence maps? With respect to the first research question, it is expected that the availability of a construction kit improves the quality of the design process. More specifically, perceived satisfaction, efficiency, control, and support are expected to increase, whereas invested mental effort (i.e., cognitive load) and time for performing the task are expected to decrease if a construction kit is available. Because a construction kit offers tools that take over routine aspects of the design task, it frees up processing resources that task performers can then use to perform the problem-solving aspects of the task (Norman, 1993). Furthermore, a phenomenarium is expected to improve process quality because it provides worked examples that may be used as analogies to perform the task at hand. It has been well documented in the literature that analogies enhance reasoning and problem solving processes (e.g., Gick & Holyoak, 1980; Holyoak & Thagard, 1995), and that worked examples are extremely important to guide novices' design processes (e.g., Renkl & Atkinson, 2003; Sweller, van Merriënboer, & Paas, 1998). An information bank is also expected to improve the process quality because it provides clear descriptions of the goals that should be reached by the task performer, as well as guidelines and heuristics that may help to reach those goals (Anderson, 1985; Reitman, 1964). However, a condensed information bank is probably more effective than an information bank with comprehensive prescriptions and explanations. Work on "minimal manuals" in the field of Minimalism has consistently found that less information is typically more effective than more information (see Carroll, 1998; van der Meij, 2003; van der Meij & Carroll, 1998), and work in the field of multimedia has found that concise explanations, which leave out interesting but irrelevant materials (also called "seductive details"), are more effective than embellished explanations (e.g., Mayer, Heiser, & Lonn, 2001; Moreno & Mayer, 2000).

With regard to the second research question, we expected an increase of perceived usability, clarity and trust when a construction kit, phenomenarium and information bank were available. If those supportive aids indeed improve process quality, it seems obvious that they enhance product quality as well. However, an important mediating factor between the process and the product quality pertains to the design characteristics of the supportive aids. For example, a construction kit incorporates some predetermined choices on the ingredients of the intended product. When these choices are sub optimal, the construction kit may be helpful for the user because it simplifies the process, but nevertheless yield a low product quality. This may be compared to the use of templates in a word processor; in general, such templates simplify the writing process but if they are badly designed they may nevertheless have a negative effect on the product. In order to prevent this discrepancy between process and product quality, the design characteristics of the supportive aids should be carefully assessed beforehand.

With regard to the third and last research question, we expected that supportive aids are helpful to perceived learning. The availability of a construction kit does not primarily support theoretical thinking or considerations at a meta-level, but clearly provokes learning-by-doing. It invites the user to actively work with predefined parts and processes, which facilitates inductive learning processes. Furthermore, a phenomenarium evokes analogical thinking: Users learn in terms of stored solutions, adaptation to new problems and generalized schemas (Thagard, 1996). Similarly, research has shown that the study of worked examples, if properly designed, leads to better schema acquisition and transfer performance than solving the equivalent problems does (e.g., Paas, 1992; Paas & van Merriënboer, 1994). Finally, an information bank provides materials for the early phase of cognitive skill acquisition, that is, the acquisition of domain knowledge (Van Lehn, 1996). It is expected that especially condensed information banks will improve learning, because novices learn more from a summary than from a full text (Reder & Anderson, 1980, 1982) and “a text that spells everything out and explains everything to the last detail does not leave enough room for constructive activities on the part of the learner” (Kintsch, 1994, p. 301).

We tested the effect of a construction kit, phenomenarium, and information bank on perceived process quality, product quality and learning in a factorial experiment. Eight conditions were designed, containing a task manager plus one of the eight possible combinations of construction kit (present or absent), phenomenarium (present or absent) and information bank (full or condensed). Participants had to construct several components of a competence map while working in one of the eight conditions. The effect of a construction kit was tested by comparing the group with a construction kit to the group without a construction kit. The effect of the phenomenarium was tested in a similar way. To test the effect of an information bank, we compared the group with a full information bank to the group with a condensed information bank.

Method

Participants

The participants were 266 first-year students from the Department of Education of the University of Gent in Belgium (239 females and 27 males; aged between 17 and 33 years, $M = 18.54$, $SD = 1.51$). Note that because the participants were all students at the same university, the generalizability of the findings is limited. The experiment was part of a regular, introductory course on educational design. All students were obliged to participate in the three-hours experiment. At the time of the experiment the students had not received any lessons on competence-based education, the construction of competence maps, or the significance of competencies for the field of education. In each session the participants were randomly assigned to one of the eight conditions. The size of the experimental groups is between 32 and 34 participants.

Materials

COMET. COMET (a loose acronym for Competence Modelling Toolkit) incorporates a task manager as well as a construction kit, phenomenarium and information bank. It is a Web-based tool designed to support educational practitioners in constructing a competence map. In particular, COMET provides support for overcoming the conceptual and procedural bottlenecks that are related to the design of competence maps (see Introduction). The *conceptual support* that COMET provides is based on dimensions of competence, that provide guidance to think about the term competence and allow flexibility in choice and personalization of a competence definition. The *procedural support* of COMET is adaptive to all kinds of competence definitions and distinguishes four steps in describing and ordering competencies. The first step concerns the construction of a linguistic format, that is, a framework for describing competencies. It defines which elements should be incorporated in competence descriptions, for example the name of a competency, the relationships with other competencies, the levels that are distinguished within the competency, and so forth. In the second step data are gathered, for example from the relevant literature, field experts and practitioners. These data provide the material from which competencies are derived and described, which is done in step three. These detailed competence descriptions are the basis for developing a competence-based educational program or curriculum. In step four, the competence descriptions are put into a competence figure. This is essentially a visual summary of the competencies, for example a pie chart, matrix or hierarchical tree structure. The competence figure provides an overall impression and serves as the signboard of a competence map. A detailed description of the design of COMET can be found in Stoof et al. (2005).

COMET has been developed by means of evolutionary prototyping (e.g., Nieveen, 1999), focusing on its usability, quality of content and quality of supportive aids. People involved in the evaluation cycles were domain experts and intended users, both novices and experts in the field of competence-based education. Usability tests show that COMET is practical (Stoof, et al., 2005). Note that all texts in COMET are in Dutch, since COMET is primarily developed for institutes of higher education in The

Netherlands.

In COMET, the task manager provides information about when to take which step. It mainly consists of navigation facilities plus a description of each step in one or two sentences. The construction kit contains small tools that support users in taking a certain step. For instance, one tool generates a partially filled out template for a competence definition, just by clicking on some statements. The phenomenarium provides examples that illustrate the application of one or more steps. In COMET, all examples are related to an invented case in which a design team in an institute for higher professional education constructs a competence map in a stepwise manner. It contains procedural information, intermediate products and final products. The information bank contains detailed descriptions of every step, with suggestions about how to take the step, warnings about pitfalls and tips how to avoid them, and information about things that should specifically be looked after.

Because of the factorial design of the present study, eight different versions of COMET were developed. Each version contained the task manager plus one of the eight possible combinations of factors and levels. The factor construction kit and the factor phenomenarium contain the levels “present” and “absent”. The factor information bank contains the levels “full”, with detailed steps, suggestions and tips; and “condensed”, where the steps have been reduced from an extensive text to only three to five sentences by an independent person. The combinations of factors and levels are expressed in the names of the eight versions of COMET: INFPHECON, INFCON, INFPHE, INF, PHECON, CON, PHE and TM-ONLY (see Table 1). For example, version INFPHECON contains a full information bank (INF), a phenomenarium (PHE) and a construction kit (CON). Note that version TM-ONLY provides the least support, with only a task manager (TM) and a reduced information bank. Figure 1 shows one of the pages of the INFPHECON-condition.

*** INSERT TABLE 1 AND FIGURE 1 ABOUT HERE ***

Manual. The manual contained information about the purpose and procedure of the experiment; some background-information about competencies, competence maps, competence-based education and COMET; and finally three tasks. Participants were asked to construct three parts of a competence map for the area of education: (1) a definition of competence, (2) a linguistic format, and (3) a competence figure.

These tasks pertain to the bottlenecks as described in the Introduction. For the other steps from the six-step model (i.e., data gathering, description of competencies, and specification of general information) no task was given. In advance to the experiment the manual had been tested to make sure that the participants were able to complete the tasks within the available time.

Cognitive load measures. Being one of the process variables, cognitive load refers to the mental effort participants put into completing the steps. In the manual, each of the four tasks was followed by one question on cognitive load (adopted from Paas, 1992 and Paas, van Merriënboer, & Adam, 1994), to be scored on a 9-point Likert-scale (1 = very, very low mental effort; 9 = very, very high mental effort). Cognitive load was treated as one aspect of process quality, that is, if performance of a task requires little effort this is seen as one indicator of high process quality.

Time investment. Participants were asked to note down the time as given by the computer clock directly after finishing the final task.

Questionnaire. The questionnaire consisted of 97 statements, to be scored on a 7-point Likert-scale (1 = absolutely not true; 7 = absolutely true). The questionnaire was developed in order to measure process quality, product quality, and learning effect. In addition to the cognitive load measures, *process quality* was measured in the questionnaire by four dependent variables: satisfaction, efficiency, control, and support. Satisfaction is defined as the amount in which users are content when working on the tasks and on the construction of a competence map in general. Statements on satisfaction were adopted from the questionnaires described by Deci, Eghrari, Patrik and Leone (1994), and Ryan, Connell and Plant (1990). Efficiency is the degree to which users have the feeling not to spend too much time on tasks. Control is the extent to which users know what to do and how to do it. Support is the amount of help users experience in using COMET. Every process variable contained statements concerning the three separate tasks in the manual, and the tasks in general. For example, satisfaction was measured with respect to the task of making a competence definition, the task of making a linguistic format, the task of making a competence figure, and the tasks in general. The *product quality* was made operational in three dependent variables: Usability, clarity and trust. Usability is the extent to which users think that products can be used for the purpose they have been made for. Clarity is the extent to which users think that products do not contain ambiguous words or concepts. Trust, finally, is the measure in which users are pleased with their products and have confidence in them. Similar to the process variables, all product variables contained statements concerning both the three separate tasks and the tasks in general. Statements on *learning effect* only concerned the tasks in general.

In addition to the statements on process quality, product quality and learning effect the questionnaire contained three single statements on possible confounders: problems with using COMET, such as not being able to open certain pages; clarity of the tasks; and the amount of prior knowledge on competence maps, competence-based education and competencies in general. The statements on all dependent variables were reliable. The questionnaire has been screened on the correct use of the Dutch language as employed in the Flemish part of Belgium. Table 2 gives an overview of all dependent variables, the number of items, and reliability measures.

*** INSERT TABLE 2 ABOUT HERE ***

Procedure

The experiment was conducted during seven sessions, spread over three days. Students were explicitly asked not to communicate with other students about the experiment afterwards. All participants were provided with a manual, scrap paper, a questionnaire, and a computer that could be used to consult one of the eight versions of COMET. After a short introduction to the experiment, participants individually worked on the three tasks described in the manual (135 minutes at most). When the participants started with reading the manual, the experimenter noted down the time as given by the computer clock. The tasks described in the manual were supported by COMET. At five predetermined moments, the session leader gave a notification to all participants in order to make sure that they would not run out of time. Participants were allowed to do something else after completing the tasks. The participants simultaneously filled out the questionnaire after a sign of the session leader (at most 25 minutes were available for this).

Analysis

The present study delivered quantitative data about process quality, product quality and learning effect when using the different versions of COMET. Except for two dependent variables, data expressed the extent to which participants agreed with positively formulated statements on perceived process quality, product quality and learning effect, as indicated by scores between 1 (“absolutely not true”) and 7 (“absolutely true”). Data on the dependent variable cognitive load expressed the mental effort that participants experienced while doing the tasks, as indicated by scores between 1 (“very, very low mental effort”) to 9 (“very, very high mental effort”). Data on the dependent variable time investment were direct measures of the amount of time that participants had spent on the tasks.

Because of the factorial design of the study, data were linked to the three factors: construction kit, phenomenarium and information bank. That is, the conditions INFPHECON, INFCON, PHECON, and CON represented data of the presence of a construction kit, whereas the conditions INFPHE, INF, PHE and TM-ONLY represented data of the absence of a construction kit. Similarly, the conditions INFPHECON, INFPHE, PHECON and PHE represented data of the presence of a phenomenarium, whereas the conditions INFCON, INF, CON and TM-ONLY represented data of the absence of a phenomenarium. Finally, the conditions INFPHECON, INFCON, INFPHE and INF represented data of a full information bank, whereas the conditions PHECON, CON, PHE and TM-ONLY represented data of a condensed information bank.

We conducted a multivariate analysis of variance (MANOVA) for *process quality* with a construction kit (present or absent), a phenomenarium (present or absent), and an information bank (full or condensed) as between-subjects factors, and satisfaction, efficiency, control, support, cognitive load and time investment as dependent measures. This overall MANOVA included data from task 1 (definition of competence), task 2 (linguistic format) and task 3 (competence figure). In addition, we conducted three separate MANOVA’s for the single tasks, taking into account data from either task 1, 2 or 3. We also conducted an overall MANOVA for *product quality* with the same between-subjects factors and with usability, clarity and trust as dependent measures. Again, we conducted three separate MANOVA’s on the data of either task 1, 2 or 3. Finally, we conducted an univariate analysis of variance (ANOVA) for *learning effect*, again with construction kit, phenomenarium and information bank as between-subjects factors. In all analyses, statistical assumptions were considered. Post-hoc analyses on the MANOVA’s were conducted by means of univariate ANOVA’s. For all statistical analyses, a significance level of .05 was applied.

Results

Table 3 shows the means and standard deviations of all dependent measures for the eight different conditions. Means on the three possible confounders: problems in using COMET, task clarity, and prior knowledge, were roughly equal for all conditions.

Process Quality

The overall MANOVA showed a main effect of the construction kit on process quality, Wilks' Lambda = .66, $F(6, 253) = 21.50$, $p < .001$. Univariate ANOVA's demonstrated that this effect was due to the dependent variables support, $F(1, 258) = 75.93$, $MSE = 99.46$, $p < .001$, $\eta^2 = .23$, control, $F(1, 258) = 18.62$, $MSE = 19.60$, p <.001, $\eta^2 = .07$, time investment, $F(1, 258) = 7.62$, $MSE = 4004.06$, $p = < .01$, $\eta^2 = .03$, and efficiency, $F(1, 258) = 7.04$, $MSE = 7.10$, $p < .01$, $\eta^2 = .03$. In the group with a construction kit, support and control are judged higher (in order $M = 5.05$, $SD = 1.21$ for support, and $M = 3.80$, $SD = 1.08$ for control) than in the group without a construction kit ($M = 3.83$, $SD = 1.25$ and $M = 3.25$, $SD = 1.02$, respectively). In contrast, time investment is higher in the group with a construction kit ($M = 120.77$, $SD = 25.42$) than in the group without a construction kit ($M = 113.00$, $SD = 22.08$). Finally, the group with the construction kit judges efficiency lower ($M = 4.63$, $SD = 1.06$) than the group with no construction kit ($M = 4.96$, $SD = 0.93$).

In addition, the overall MANOVA showed a main effect of the phenomenarium on process quality, Wilks' Lambda = .87, $F(6, 253) = 6.36$, $p < .001$. Univariate ANOVA's revealed that the effect was caused by the dependent variables support, $F(1, 258) = 31.01$, $MSE = 12.99$, $p < .001$, $\eta^2 = .11$, and control, $F(1, 258) = 12.33$, $MSE = 12.99$, $p < .01$, $\eta^2 = .05$. In the group with a phenomenarium, support and control are judged higher ($M = 4.83$, $SD = 1.29$ for support, and $M = 3.75$, $SD = 1.11$ for control) than in the group without a phenomenarium ($M = 4.04$, $SD = 1.35$ and $M = 3.30$, $SD = 1.01$, respectively).

Finally, the overall MANOVA showed an interaction effect of the phenomenarium and construction kit on process quality, Wilks' Lambda = .94, $F(6, 253) = 2.72$, $p < .05$. According to univariate ANOVA's this effect was caused by the dependent variable support, $F(1, 258) = 7.83$, $MSE = 10.26$, $p < .01$, $\eta^2 = .03$. Figure 2a shows the interaction effect on support. If there is no phenomenarium, the absence of the construction kit greatly decreases the experienced support; if there is a phenomenarium, the absence or presence of the construction kit has relatively little effect on perceived support. There were no other interactions and there was no main effect of the information bank.

The separate MANOVA taking into account only data related to the linguistic format revealed two findings that had not been found in the overall MANOVA. First, the separate MANOVA showed a main effect of the construction kit on process quality, Wilks' Lambda = .68, $F(5, 251) = 24.12$, $p < .001$. In addition to results that were already found in the overall MANOVA, univariate ANOVA's showed a significant effect on cognitive load, $F(1, 255) = 12.68$, $MSE = 30.29$, $p <.001$, $\eta^2 = .05$. In the group with a construction kit, cognitive load is judged lower ($M = 5.49$, $SD = 1.62$) than in the group without a construction kit ($M = 6.17$, $SD = 1.45$). Second, the separate MANOVA showed an interaction effect of the phenomenarium and construction kit on process quality, Wilks' Lambda = .93, $F(5, 251) = 3.63$, $p < .01$. In addition to the results of the overall MANOVA, univariate ANOVA's showed a significant effect on control, $F(1, 255) = 4,52$, $MSE = 7.22$, $p <.05$, $\eta^2 = .02$. Figure 2b shows the interaction effect on control. If there is no phenomenarium, the absence of the construction kit greatly decreases the experienced control; if there is a phenomenarium, the absence or presence of the construction kit has relatively little effect on perceived control.

*** INSERT FIGURE 2 ABOUT HERE ***

Product Quality

The overall MANOVA showed no main effects of the construction kit, phenomenarium or information bank on product quality. However, the separate MANOVA taking into account only data related to the competence figure, revealed an interaction effect of the construction kit and the information bank on product quality, Wilks' Lambda = .97, $F(3, 255) = 2.99$, $p < .05$. Univariate ANOVA's demonstrated that this effect was due to the dependent variables trust, $F(1, 257) = 5.66$, $MSE = 10.82$, $p < .05$, $\eta^2 = .02$, and usability, $F(1, 257) = 4.27$, $MSE = 7.41$, $p < .05$, $\eta^2 = .02$. Figure 3a shows the interaction effect on trust. If there is a condensed information bank, the availability of the construction kit greatly enhances perceived trust; but if there is a full information bank, the availability of the construction kit has a reversed effect on trust. Figure 3b shows a similar interaction effect on usability.

*** INSERT FIGURE 3 ABOUT HERE ***

Learning Effect

The overall univariate ANOVA showed a main effect of the phenomenarium on learning effect, $F(1, 258) = 5.23$, $MSE = 8.43$, $p < .05$, $\eta^2 = .0.20$. In the group with a phenomenarium, learning effect is judged higher ($M = 4.41$, $SD = 1.18$) than in the group without a phenomenarium ($M = 4.05$, $SD = 1.37$). Also, a main effect was found of the construction kit on learning effect, $F(1, 258) = 4.69$, $MSE = 7.55$, $p < .05$, $\eta^2 = .02$. In the group with a construction kit, learning effect is judged higher ($M = 4.40$, $SD = 1.25$) than in the group without a construction kit ($M = 4.06$, $SD = 1.31$). There was no main effect of the information bank and there were no interactions.

*** INSERT TABLE 3 ABOUT HERE ***

Discussion and Conclusion

This study investigated whether a construction kit, phenomenarium, and information bank improve the quality of the process of making a competence map, the quality of the resulting products, and the perceived effects on learning to construct competence maps. In a factorial design, eight conditions with all possible combinations of construction kits (present or absent), phenomenaria (present or absent) and information banks (full or condensed) were compared. Participants used different combinations of supportive aids while they performed three tasks and then rated perceived process and product quality as well as effects on learning.

Question 1: Do construction kits, phenomenaria and information banks improve the quality of the process of making competence maps?

The results of our study clearly indicate that the availability of a construction kit enhances the perceived support and control, as expected. Thus, designers who construct—parts of—a competence map with a construction kit experience more help from COMET and know better what to do and how to do it than designers who do not use a construction kit. However, the availability of the construction kit decreases perceived efficiency, indicating that users feel that they spend too much time on the construction of the competence map. This is confirmed by measured time investment: Designers who work with the construction kit spend more time constructing the map than designers without the kit. This is not in agreement with our hypothesis. A possible explanation is that the availability of the construction kit raises additional questions about the task, thereby extending rather than reducing the construction process. Another explanation is that it takes additional time to learn how to use the construction kit; a further optimisation of the usability and learnability of the kit might possibly reduce this extra learning time. In addition to the effects on perceived support, control, time investment and efficiency, there were indications that the availability of a construction kit somewhat decreases cognitive load. This supports our presumption that a construction kit frees up processing resources by taking over routine aspects of the task.

With regard to the phenomenarium, the results show that its availability improves perceived support and control as well. This is in line with our expectations. Furthermore, the effect of the availability of a phenomenarium is mediated by the availability of a construction kit. If there is no phenomenarium, the absence of a construction kit greatly decreases experienced support; but if there is a phenomenarium, the absence or presence of a construction kit has relatively little impact on perceived support.

No direct effect was found for the comprehensiveness of the information bank on process quality. This indicates that it does not matter whether a full or a condensed information bank is used for supporting designers in the process of constructing competence maps. This is in contrast to our hypothesis stating that minimal information improves process quality more than full information. Regarding the vast amount of evidence in favour of short texts and minimal information, a possible explanation may be found in the design of this particular study. Perhaps results would have been different if process quality was measured by other, more sensitive variables; as indicated below, it happens that a condensed information bank in combination with a construction kit shows higher perceived *product* quality than a full information bank (in particular, for perceived trust and usability).

Summarizing, a construction kit and a phenomenarium improve the quality of the process of making a competence map, in particular with respect to the process variables support, control and cognitive load. But when designers already have a phenomenarium at their disposal, a construction kit does not significantly enhance perceived process quality. Furthermore, our results indicate that the availability of a construction kit leads to higher time investment and a decrease of perceived efficiency.

Question 2: Do construction kits, phenomenaria and information banks improve product quality?

As indicated above, the availability of a construction kit enhances perceived trust and usability if there is an information bank with condensed information. But if there is a full information bank, the availability of the construction kit has a reversed and smaller effect on trust and usability. Thus, the amount to which designers are pleased with their products and have confidence in them, and the amount to which users think that products can be used for the purpose they have been made for, may be improved by offering them the combination of a condensed information bank and a construction kit. This points to a tendency in favour of the condensed information bank above the full information bank, as hypothesized.

Question 3: Do construction kits, phenomenaria and information banks lead to positive effects on learning to construct competence maps?

Our results clearly indicate a positive effect of the availability of a construction kit and the availability of a phenomenarium on perceived learning about competence maps and their construction. This is in accordance with our expectations, although no effects of the nature of the information bank were found.

Despite the promising results of this study, five remarks are in place. First, the generalizability of the findings is limited because the participants were all students at the same university.

Second, all results (except for time investment) pertain to participants' perceptions rather than direct measures. Obviously, the findings would be even more convincing when they were corroborated by direct measures. For example, the quality of products such as competence definitions, linguistic formats and competence figures could be measured by independent raters on the basis of a list of criteria, and learning outcomes could be measured by traditional knowledge and skills tests. Whereas it may be difficult to develop hard criteria due to a lack of reference products (e.g., there is no generally accepted definition of competence, see Stoof et al., 2002), future research should also include more direct measures of product quality and learning outcomes.

Third, the set up of our study warranted good experimental control but did this at the cost of a high ecological validity. Freshman in the domain of educational sciences worked individually for three hours on an invented task (although this task was as realistic and recognizable as possible). In educational practice, competence maps are typically constructed by heterogeneous teams, consisting of teachers, educational managers and field experts. These teams work on the construction of a competence map for several weeks or even months, in a process that is characterized by negotiation and reaching agreement on several issues (see Stoof et al., 2004; Tilman & Stoof, 2002). Therefore, it would be of great interest to see whether the results of the current study can be replicated by future studies that take place in an ecologically valid setting.

Fourth, we did not study the effects of the final competence map, constructed with or without supportive aids, on the design characteristics of a competence-based curriculum. In general, this kind of proof is rare in research on instructional design (Gustafson, 2002). Comparative research is extremely difficult to conduct because the research context (e.g. educational sector), the composition of the project team, and the purpose of the competence map should be similar across experimental groups. Another difficulty is that the effect of a competence map can only be measured after at least one year, after it has actually been used for curriculum design. Despite these difficulties, it is a challenge for future research to collect this kind of conclusive evidence.

A fifth and final remark concerns the way in which the construction kit, phenomenarium and information bank were designed and technically implemented in this study. A lot of effort has been put into the selection and description of the contents and the design of the interface of the three types of supportive aids, for example by having them repeatedly evaluated by domain experts and intended users in advance to the experiment (see Stoof et al., 2005). However, supportive aids can be designed in many different ways. The results of this study are promising with respect to the effects of construction kits and phenomenaria, and to a lesser extent to condensed information banks, but it would be very interesting to evaluate supportive aids designed and implemented in another way than the ones used in this study.

To conclude, we will discuss the practical implications of our study using the format for reporting design principles proposed by Van den Akker (1999). In general, a Web-based support system may help designers to construct a competence map as a basis for the development of competence-based education, and in particular help them to deal with the conceptual and procedural bottlenecks that are related to this task. The Web-based system should at least include a construction kit and a phenomenarium; a possible information bank should include condensed instead of full information. The results of our study indicate that these supportive aids lead to an improvement of perceived process quality, learning effect and—to a lesser degree—product quality. There is one remark with respect to the availability of a construction kit. When a construction kit is present, more time is needed to construct parts of a competence map than when a construction kit is absent. If development time is very limited, one may consider using a Web-based support system without a construction kit but with a phenomenarium and a condensed information bank only.

A construction kit should be designed in such a way that it frees up processing resources because it takes over the routine aspects of the task of making a competence map (Norman, 1993). A construction kit should thus direct the users' attention to core aspects of the task and translate the routine aspects into prefabricated processes and parts. Furthermore, it should invite users to actually do things and not bother them with peripheral issues that can be dealt with later. Then, it provokes learning-by-doing and fosters inductive learning. A phenomenarium should contain useful analogies and worked examples. These will typically be based on real-life development processes of project teams that have been constructing competence map (i.e., case studies). Analogies and worked examples enhance task performance and help users to learn about competence maps and their construction because they facilitate the acquisition of cognitive schemas. Guidelines for constructing optimal worked examples can be found in Ward and Sweller (1990), Paas and van Merriënboer (1994) and Sweller et al., (1998). An information bank should contain general information about valuable goals and guidelines for reaching those goals. For example, an information bank on the construction of a competence definition should tell the user what a competence definition looks like and what its main features are. In addition, it should recommend guidelines and heuristics that may be helpful to devise a definition. In general, the amount of information should be kept as small as possible, since results are then best with respect to process quality and learning effect (e.g., Kintsch, 1994).

For all types of supportive aids, including construction kits, phenomenaria and information banks, their design should be based on a thorough analysis of the task of constructing a competence map as well as the knowledge that is necessary for the effective and efficient performance of this task (Stoof et al., 2005). It is strongly recommended to involve task experts in the analysis and design process, and to repeatedly test the supportive aids with real users in a process of rapid prototyping. Our study shows that some designers appreciate well-designed Web-based support for constructing competence maps and it provides valuable directions for future research that should focus on curriculum effects in ecologically valid educational settings.

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Table 1

Description of the Eight Different Conditions

		Information bank			
		full		condensed	
		Construction kit		Construction kit	
		present	absent	present	absent
Phenomenarium	present	INFPHECON	INFPHE	PHECON	PHE
	absent	INFCON	INF	CON	TM-ONLY

Table 2

An Overview of the Dependent Measures and their Internal Consistencies

		Number of items	Cronbach's α
Process quality	Satisfaction	12	.91
	Efficiency	12	.88
	Control	12	.88
	Support	12	.94
	Cognitive load	4	.68
	Time investment	1	-
Product quality	Usability	15	.85
	Clarity	12	.89
	Trust	12	.91
Learning effect		6	.89

Table 3

Means and Standard Deviations of the Measures in the Eight Conditions

		INFPHECON (*n* = 32)		INFCON (*n* = 33)		INFPHE (*n* = 32)		INF (*n* = 34)		PHECON (*n* = 33)		CON (*n* = 34)		PHE (*n* = 34)		TM-ONLY (*n* = 34)	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Process quality	Satisfaction	2.89	1.04	2.17	1.06	2.97	1.06	3.03	1.13	3.54	1.09	3.23	1.03	3.23	1.16	3.09	1.17
	Efficiency	4.55	0.93	4.54	0.98	5.08	0.82	4.86	0.99	4.79	1.17	4.67	1.18	4.81	0.90	5.09	1.00
	Control	3.75	1.09	3.61	1.08	3.41	1.07	2.93	0.95	4.17	1.08	3.65	1.02	3.73	1.03	2.95	0.82
	Support	4.89	1.37	4.78	1.30	4.22	1.15	3.18	0.97	5.64	0.90	4.90	1.07	4.69	1.22	3.25	0.99
	Cognitive load	6.16	0.87	6.33	0.91	6.39	0.94	6.18	0.95	6.27	0.97	6.03	1.29	6.38	1.05	6.21	0.83
	Time investment	120.03	3.01	120.06	3.50	111.13	3.71	114.35	4.24	124.76	4.91	118.29	4.61	112.90	3.45	113.53	3.94
Product quality	Usability	4.22	0.81	4.17	0.78	4.26	0.87	4.05	1.09	4.42	0.61	4.27	0.75	4.39	0.78	4.06	1.06
	Clarity	3.99	0.96	3.93	0.82	3.73	0.91	4.05	1.13	3.84	0.78	3.95	0.80	3.90	1.04	4.15	0.85
	Trust	3.39	1.05	3.32	1.11	3.52	1.13	3.38	1.23	4.00	0.81	3.64	1.02	3.83	1.01	3.27	1.02
Learning effect		4.22	1.17	4.31	1.45	4.18	1.25	3.68	1.48	4.73	1.03	4.33	1.31	4.59	1.10	3.78	1.22

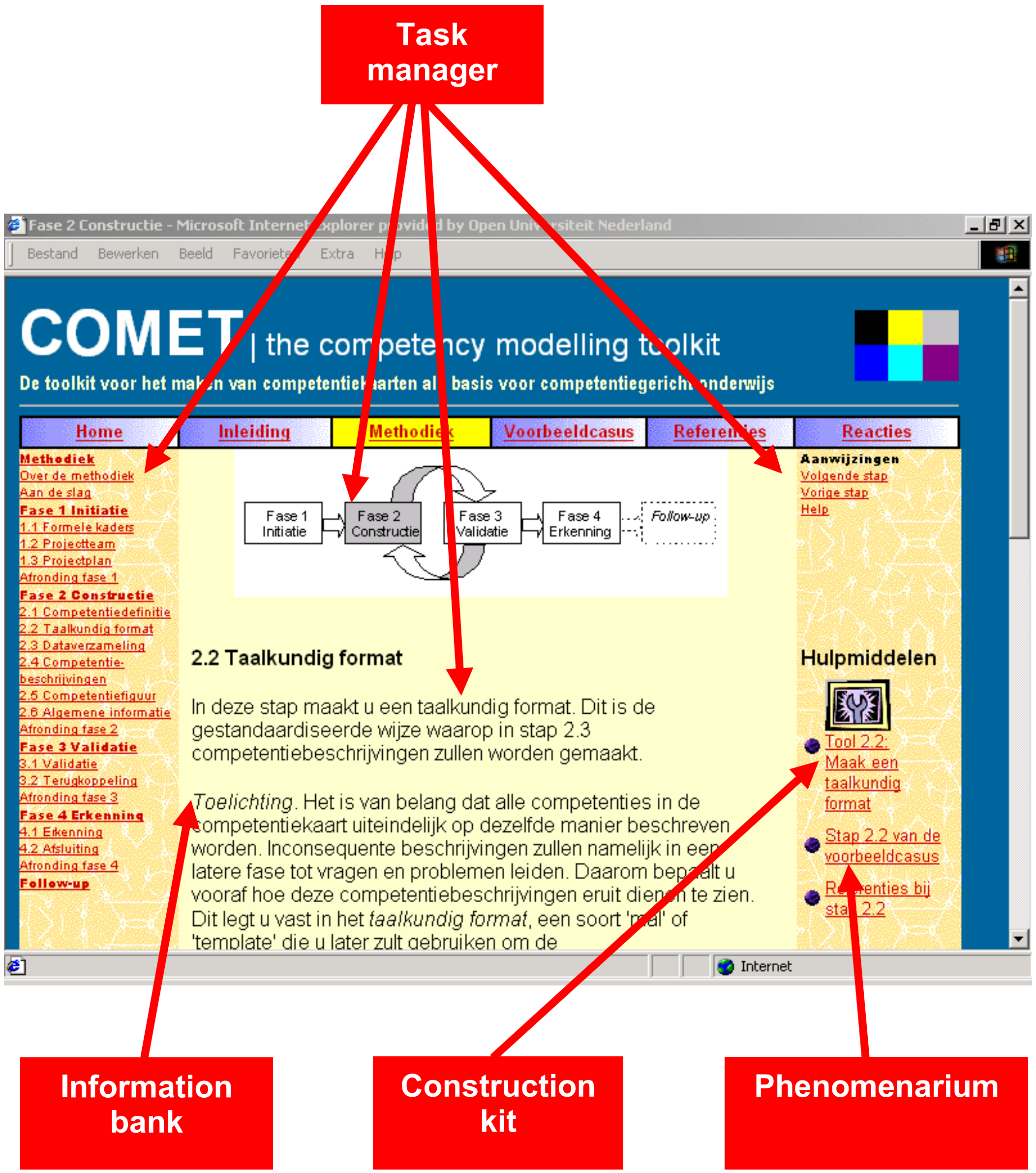
Note. Scores range from 1 to 7 for all measures except for cognitive load (ranges from 1 to 9) and time investment (in minutes).

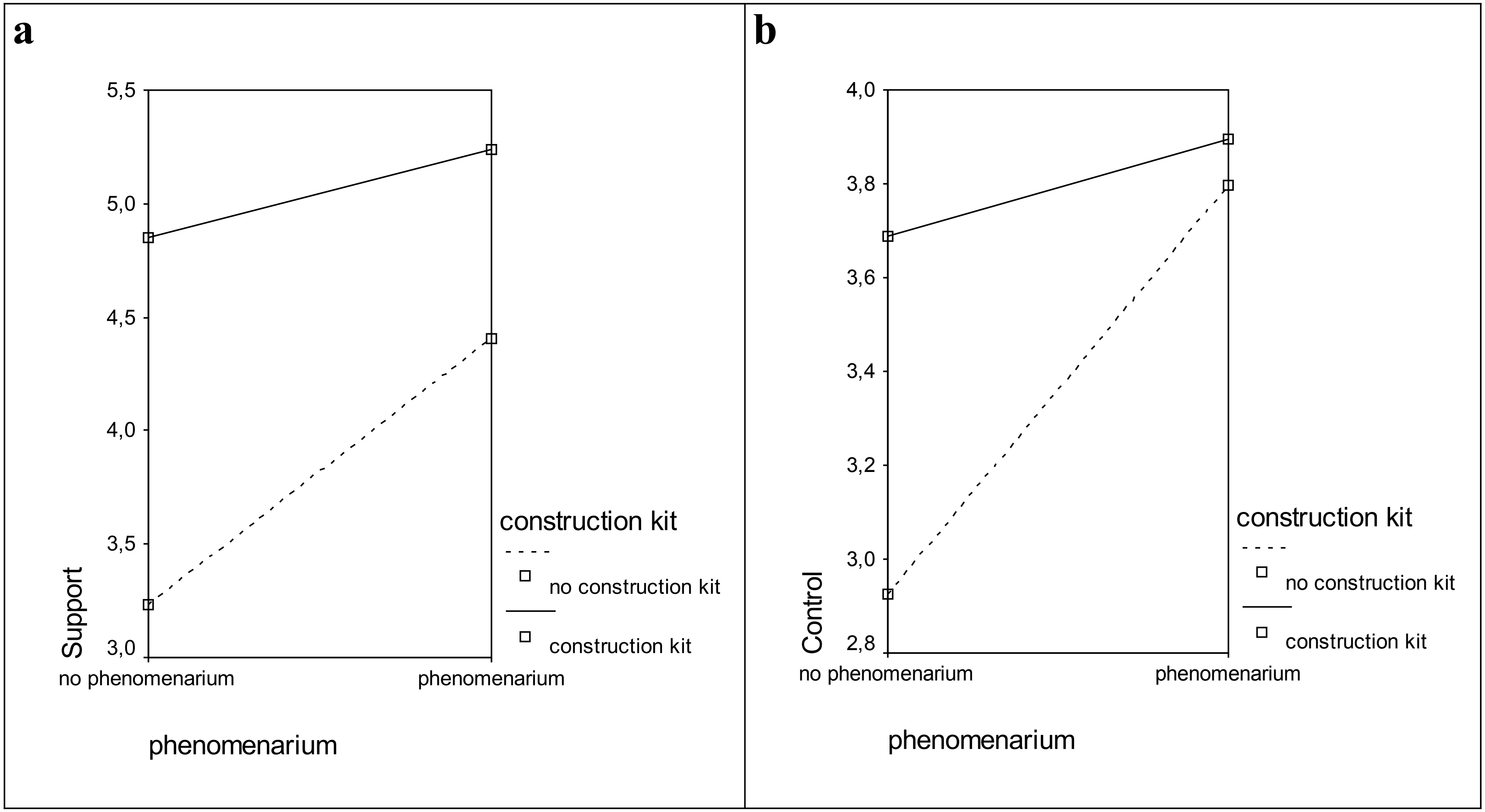
Figure Captions

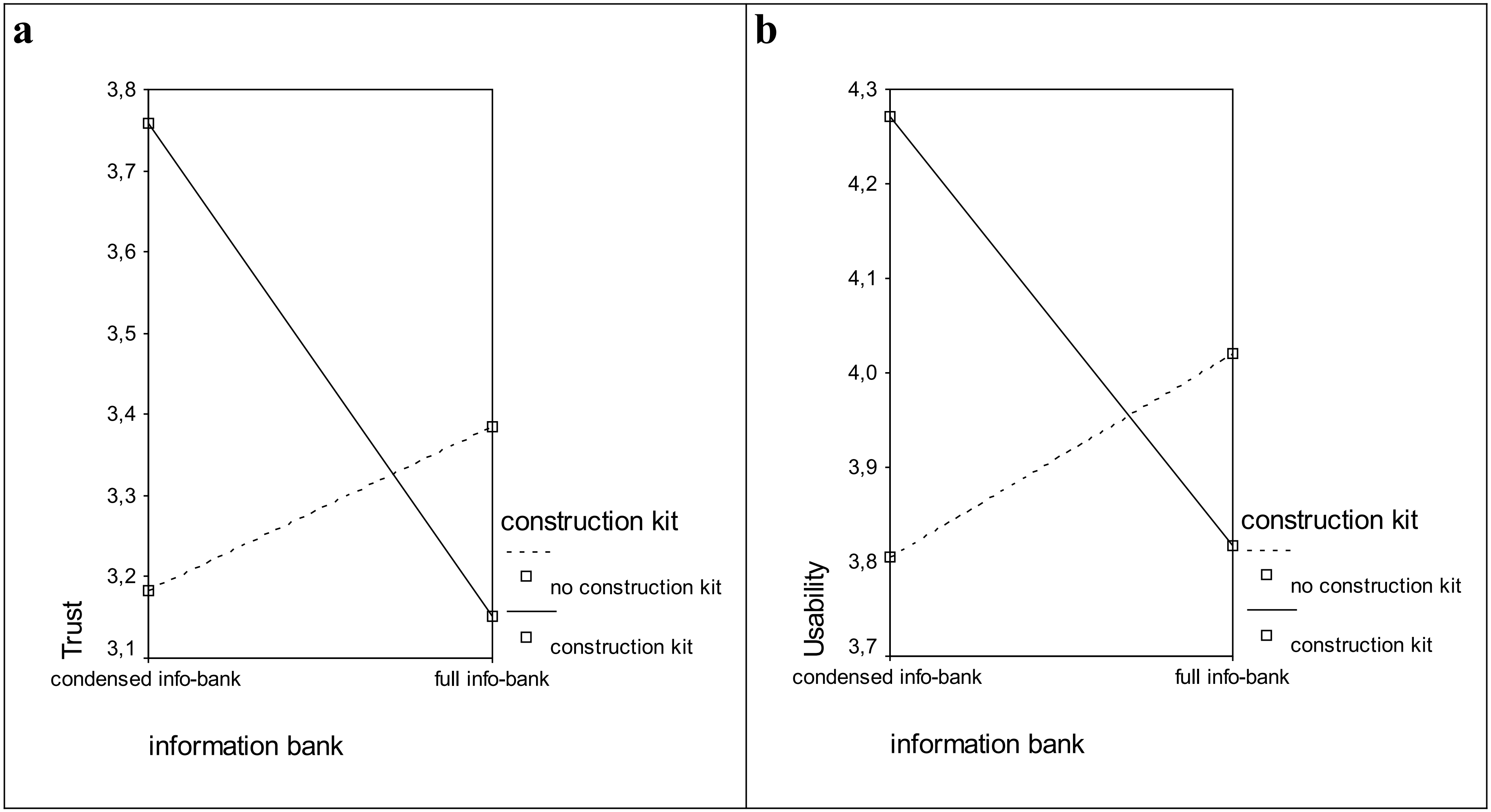
Figure 1. A screen capture of COMET showing the task manager and the three supportive aids.

Figure 2. Interactions of Phenomenarium x Construction kit on two measures of process quality: Perceived support (part A) and control (part B).

Figure 3. Interactions of Information bank x Construction kit on two measures of product quality: Perceived trust (part A) and usability (part B).


Task manager
Fase 2 Constructie - Microsoft Internet Explorer provided by Open Universiteit Nederland
Bestand Bewerken Beeld Favorieten Extra Help
COMET | the competency modelling toolkit
De toolkit voor het maken van competentiekaarten als basis voor competentiegericht onderwijs
Home
Inleiding
Methodiek
Voorbeeldcasus
Referenties
Reacties
Methodiek
Over de methodiek
Aan de slag
Fase 1 Initiatie
1.1 Formele kaders
1.2 Projectteam
1.3 Projectplan
Afronding fase 1
Fase 2 Constructie
2.1 Competentiedefinitie
2.2 Taalkundig format
2.3 Dataverzameling
2.4 Competentie-beschrijvingen
2.5 Competentiefiguur
2.6 Algemene informatie
Afronding fase 2
Fase 3 Validatie
3.1 Validatie
3.2 Terugkoppeling
Afronding fase 3
Fase 4 Erkenning
4.1 Erkenning
4.2 Afsluiting
Afronding fase 4
Follow-up
Fase 1 Initiatie
Fase 2 Constructie
Fase 3 Validatie
Fase 4 Erkenning
Follow-up
2.2 Taalkundig format
In deze stap maakt u een taalkundig format. Dit is de gestandaardiseerde wijze waarop in stap 2.3 competentiebeschrijvingen zullen worden gemaakt.
Toelichting. Het is van belang dat alle competenties in de competentiekaart uiteindelijk op dezelfde manier beschreven worden. Inconsequente beschrijvingen zullen namelijk in een latere fase tot vragen en problemen leiden. Daarom bepaalt u vooraf hoe deze competentiebeschrijvingen eruit dienen te zien. Dit legt u vast in het taalkundig format, een soort 'mal' of 'template' die u later zult gebruiken om de
Aanwijzingen
Volgende stap
Vorige stap
Help
Hulpmiddelen
Tool 2.2: Maak een taalkundig format
Stap 2.2 van de voorbeeldcasus
Referenties bij stap 2.2
Internet
Information bank
Construction kit
Phenomenarium


a
5,5
5,0
4,5
4,0
3,5
3,0
Support
no phenomenarium
phenomenarium
phenomenarium
construction kit
no construction kit
construction kit
b
4,0
3,8
3,6
3,4
3,2
3,0
2,8
Control
no phenomenarium
phenomenarium
phenomenarium
construction kit
no construction kit
construction kit


a
3,8
3,7
3,6
3,5
3,4
3,3
3,2
3,1
Trust
condensed info-bank
full info-bank
information bank
construction kit
no construction kit
construction kit
b
4,3
4,2
4,1
4,0
3,9
3,8
3,7
Usability
condensed info-bank
full info-bank
information bank
construction kit
no construction kit
construction kit

Footnote

[1] The present study is part of a dissertation study.