

Web-based support for constructing competence maps: design and formative evaluation

Citation for published version (APA):

Stoof, A., Martens, R., & Van Merriënboer, J. (2007). Web-based support for constructing competence maps: design and formative evaluation. *Etr&D-Educational Technology Research and Development*, 55(4), 347-368. <https://doi.org/10.1007/s11423-006-9014-5>

DOI:

[10.1007/s11423-006-9014-5](https://doi.org/10.1007/s11423-006-9014-5)

Document status and date:

Published: 01/08/2007

Document Version:

Peer reviewed version

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
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This is a pre-print of:

Stoof, A., Martens, R. L., & Van Merriënboer, J. J. G. (2007). Web-based support for constructing competence maps: Design and formative evaluation. *Educational Technology, Research and Development*, 55(4), 347-368.

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Web-based Support for Constructing Competence Maps:

Design and Formative Evaluation

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Abstract

This article describes the design and formative evaluation of a Web-based tool that supports curriculum developers in constructing competence maps. Competence maps describe final attainment levels of educational programs in terms of - interrelated - competencies. Key requirements for the supportive tool were validity and practicality. Validity refers to internal consistency and meaningful links to the external realities represented. Practicality refers to a design approach of evolutionary prototyping, in which feedback from intended users and domain experts was collected throughout the development process. Formative evaluations of four prototypes were conducted. Measures of design, appeal, goal, content, confidence and relevance showed that the tool is practical. The article describes the formative evaluation process and concludes with a description of the final tool from the perspective of the user and the instructional designer.

The identification and description of competencies as the basis for a competence-based curriculum is characterized by several bottlenecks. This article discusses the design and formative evaluation of a Web-based tool that supports designers in overcoming these bottlenecks.

The concept of competence plays a considerable role in modern education. Institutes of middle and higher professional education and several universities in for example Australia and New Zealand (e.g., Mulcahy, 2000) and Europe adopt the concept of competence to guide the development of education programs. In the Netherlands, competence-based education is fostered by the national government and has therefore been implemented on a large scale (e.g., Mulder, Wesselink, Biemans, Nieuwenhuis, & Poell, 2003). Competence-based education may be regarded as a response to societal changes. Working situations have become more dynamic and complex, thereby posing new and specific demands to employees (Van der Klink & Boon, 2003). The term competence provides a way to think changes and requirements. Characteristics of competence-based education include a focus on authentic professional situations, tasks, and roles, from which the learning content is derived; authentic assessment in the beginning, during and after the learning process; integration of learning content across the curriculum; a view of the student as an educational self-planner; and the teacher as a learning coach (De Bie, 2003; Schlusmans, Slotman, Nagtegaal, & Kinkhorst, 1999).

An important document used in developing competence-based education is the *competence map*. This document describes the final attainment levels that define the program of study. Documents describing curriculum content generally required for instructional development, but what makes a competence map different is the terminology and focus. In a competence map, curriculum content is described in terms of interrelated competencies rather than in terms of fragmented or dissociated knowledge, skills and attitudes. Competence maps typically consist of three parts. The first part contains *competence descriptions*, which provide detailed information about each competency that is distinguished in a certain domain or profession. A competence description may contain information about its output or results, its relationships with other competencies, the elements which the competency consists of, and an example of the competency in practice. Competence descriptions are used for the design of instruction, learning tasks, and assessment procedures. The second part of a competence map consists of a

competence figure, which is a visual summary of the competence descriptions. A competence figure can be used as an aid to quickly communicate what a competence map is about. The third part of a competence map contains *general information* about the domain, the goal, and definitions used. Typically, a competence map is developed by a heterogeneous team that consists of knowledgeable people such as curriculum designers, teachers, educational managers, practitioners, field experts, branch representatives and others. The process of developing a competence map is constructed is complex and challenging, not unlike many other instructional development tasks (De Bie, 2003; McKenney, Nieveen, & van den Akker, 2002).

Empirical research has shown that the development of a competence map is made is subject to several challenges (Stoof, Martens, & van Merriënboer, 2004a). A major challenge is the definition of competence and the difference between competence and related terms such as knowledge, skills, ability, and expertise. People may not know what competence means or how it should be defined. This problem has been reported in theoretical explorations of this topic and is characteristic of the terminology problems often encountered in instructional development (e.g., Stoof, Martens, & van Merriënboer, 2002; Van Merriënboer, van der Klink, & Hendriks, 2002). Another major challenge concerns the procedure for constructing competence maps – specifically the lack of established procedures for describing competencies and ordering them into a clear framework is a major problem (see also De Bie, 2003).

A possible solution to these challenges is to support designers of competence maps with an instructional design tool that helps them to define the concept of competence and guides them through the development of a competence map. Such a tool is expected to lead to improved task performance, increased task-related knowledge, increased satisfaction and increased internal consistency of the output of instructional design and development teams (Gery, 1991; McKenney, Nieveen, & van den Akker, 2002; Stevens & Stevens, 1990). Existing instructional design tools mainly focus on development or production rather than on front-end planning and analysis (Van Merriënboer & Martens, 2002).

This article focuses on the design and formative evaluation of a supportive tool for constructing competence maps. The central research question is: What are the characteristics of a valid and practical tool that supports people conceptually as well as procedurally in constructing a competence map? The

validity of such a tool implies that it is based on state-of-the-art knowledge and that the various components of the tool are consistently linked to each other (Van den Akker, 1999). That is, the tool should be grounded in reality and be internally consistent. The *practicality* of the supportive tool holds that users and other experts consider the tool useful and usable (Van den Akker, 1999). In other words, the tool should be easy and pleasant to use, it should meet the needs and demands of the target group, and it should effectively support the task of constructing competence maps.

The next two sections describe validity and the types of supportive aids relevant to complex tasks. Subsequent sections focus on the design and formative evaluation of the tool. The final section describes how the tool was modified and provides a more general discussion of related design issues.

Conceptual and procedural support

Conceptual Support. Support for defining the term “competence” should be flexible, so that users are encouraged to define competence in a manner that suits their specific situations (Stoof, Martens, & van Merriënboer, 2004a; Stoof, Martens, van Merriënboer, & Bastiaens, 2002). That is, the conceptual support needs to be useful for defining competence in many different ways. At the same time, users need to have *some* support in the definition process. One type of flexible support is the use of dimensions to define competence.

An analysis of 16 competence maps in a wide range of domains indicated six important dimensions. The first dimension, *levels*, concerns the issue whether or not competencies can be subdivided in for example starting level, advanced level, and experienced level. The second dimension, *context*, has to do with the question whether or not competencies are connected to for example tasks, roles, functions or situations. The third dimension, *relationships*, is about the issue whether or not competencies are related to each other. In dimension four, *elements*, the issue is whether or not competencies are composed of several parts, such as knowledge, skills and attitudes. Dimension five, *output*, concerns the question whether or not competencies lead to specific outcomes, such as a product or service, or behavior in general. The sixth dimension, *kinds*, has to do with the question whether or not there are more competencies than just professional competencies, such as learning competencies, career competencies and competencies that are general to all kinds of professions. Using these dimensions to guide the definition of

the term competence enables flexibility while providing anchors.

Procedural support. Procedural support should be flexible as well. That is, procedural support should be designed in such a way that all different kinds of competence definitions can be used for describing and ordering competencies in a clear framework. Although there are many procedures for competency analysis, none of them is free of assumptions about the meaning of competence. However, these existing procedures do provide valuable information and can be adjusted, so that they can be used with alternative competence definitions. A benefit of this approach is internal consistency of steps in the development process.

With respect to the first procedural issue, *describing competencies*, procedural support can follow a three-step approach: (1) development of a linguistic format; (2) structured data collection; and (3) structured data analysis. A *linguistic format* is a template for making competence descriptions. It contains empty fields that need to be completed for each competency. The fields are similar to the dimensions of a competence definition. For example, the field of an “output slot” needs to be filled in with information about the products or services that are generated by applying a particular competency. A standard linguistic format helps users incorporate required information and ensures that every competence description contains the same type of information. The specific fields in a linguistic format are based on the user’s specific competence definition.

Data collection can be derived from linguistic format. That is, if a linguistic format contains an “output slot”, data collection should include the gathering of information about the output of competencies. In this way, data is gathered in a structured and consistent way. Existing techniques provide valuable information about data gathering. Some techniques consist of matrices that people can use to collect and represent information about competencies (Boon & van der Klink, 2001; Fletcher, 1997). Other types of support are exemplary questions that can be used in interviewing practitioners or other field experts (Boon & van der Klink, 2001; Cluitmans, 2002), and suggestions for other sources that may provide relevant information (Cluitmans, 2002).

The third step in describing competencies, *data analysis*, concerns the analysis of large amounts of qualitative data, such as interview reports and document analysis reports. The manner in which data are

analyzed depends on the linguistic format and the type of data. Techniques for qualitative data analysis (e.g., Miles & Huberman, 1984; Strauss & Corbin, 1990) and techniques for knowledge elicitation and representation (e.g., Shadbolt & Burton, 1995) can be used. The data analysis finally results in the competence descriptions.

As for the second procedural issue, *ordering competencies*, users have to organize the competencies in a general framework. This framework summarizes the most important features so that a quick overview of the competencies is obtained. There are many kinds of frameworks, such as lists, matrices, circle diagrams, pie charts, hierarchical tree structures, and so on. Procedural support should help users to choose a framework that fits their competence definition, linguistic framework and competence descriptions, and it should help them to “fill” the chosen framework with competencies.

Table 1 describes the phases and steps in the development process. In the initiation phase the user makes preparations for the construction of the competence map, by composing a project team and writing a project plan. In the construction phase, the competence map is developed. This phase contains the conceptual and procedural support. Subsequently, the competence map is validated with subject matter experts. If necessary, the competence map has to be adjusted and validated again. In the final phase, the competence map is formally acknowledged by stakeholders and is ready for implementation in the curriculum.

*** INSERT TABLE 1 ABOUT HERE ***

Supportive aids

There are many kinds of aids that may support people who make competence maps. However, four aids seem to be particularly useful for the intended tool: task managers, information banks, construction kits, and phenomenaria (Perkins, 1992). *Task managers* focus on the procedure to be followed provide descriptions of methods, rules, regulations, and directions for doing the task. Task managers should guide users in executing (sub-)tasks, provide feedback, and enable users to check whether a step has been completed. Task managers provide standardization support (Van Merriënboer & Martens, 2002). *Information banks* contain textual or visual information about the task at hand, including databases, resources, references, and help-functions that give procedural and conceptual answers to specific

questions. Information banks should contain a proper goal description (Anderson, 1985). In addition, research has shown that short texts are typically more effective than extensive ones (e.g., Carroll, 1998; Van der Meij, 2003; Van der Meij & Carroll, 1998). Information banks are also known as library and information support systems (Van Merriënboer & Martens, 2002). *Construction kits* consist of prefabricated parts and processes that may support decision making, provide warnings for the consequences of particular choices, or generate (parts of) products. Examples of construction kits are the wizards included in Microsoft™ applications and templates for documents, spreadsheets and presentations. A well-designed construction kit takes over routine aspects of the task of making a competence map, so that processing resources are released that can subsequently be used for the problem solving-aspects of the task (Norman, 1993). Construction kits are also called job aids (McKenney, Nieveen, & van den Akker, 2002) or task automation support systems (Van Merriënboer & Martens, 2002). Finally, *phenomenaria* are (case) examples, which can be based on real-life projects in which competence maps are developed. Guidelines for designing phenomenaria can be found in the literature on worked examples (e.g., Paas & van Merriënboer, 1994; Sweller, van Merriënboer, & Paas, 1990; Ward & Sweller, 1990).

The four types of aids are useful for the design of the conceptual and procedural support in different ways. As for *conceptual support*, an information bank, a construction kit and a phenomenarium can be used. An information bank provides general information about the dimensions of competence. A construction kit helps users to generate a definition by means of the dimensions. Finally, a phenomenarium provides concrete examples of both the use of dimensions for defining competence and the resulting competence definition. As for *procedural support*, all four types of aids are useful. A task manager guides the user through the steps in which competencies are described and ordered. An information bank generally describes how to generate a linguistic format, how to collect data, how to analyze data and how to choose a useful framework for organizing the competencies. A construction kit helps users to generate a linguistic format, provides templates for data collection and analysis, and helps users to choose a useful framework. Finally, a phenomenarium provides examples of processes and products with respect to a linguistic format, data collection, data analysis, competence descriptions and a framework.

Design approach

A development strategy called *evolutionary prototyping* was adopted for this project. Parts or preliminary versions of the tool are repeatedly tested and improved until a useful and usable product is developed (Nieveen, 1999). Evolutionary prototyping is a strong and effective method because it involves intended users, domain experts and others from the very beginning. Problems are identified early, revisions are made, and the process iterates until everyone is satisfied. Evolutionary prototyping is used by many tool developers (Nieveen & Gustafson, 1999) and is generally consistent with user-centered design.

An evolutionary prototyping design approach is based on a thorough analysis of the target group, their context and their needs. The target group consists of all kinds of people who may be involved in the construction of a competence map, such as curriculum designers, teachers, educational managers, practitioners, field experts and other users. Together they form a heterogeneous project team and are responsible for the design of the tool. Typically, they meet several times in a face-to-face context. E-mail and telephone calls are used for additional communication, since team members are often located at different working places. The target group has a need for supportive tools or guidelines that help them in overcoming the conceptual and procedural problems that they encounter in the construction process, as analyzed and described by Stoof, Martens and van Merriënboer (2004a).

A second prerequisite for a successful design approach is an analysis of the task and the desired output. Task analysis has already been discussed in the conceptual and procedural support section. As for the output, the tool has to generate the three parts of a competence map: competence descriptions, a competence figure, and general information about the competence map (see Introduction).

Finally, design choices in the evolutionary prototyping cycle can be based on the wide range of experiences with tool development for educational purposes. First, a tool should be adaptive and flexible, so that it meets the users' needs and wishes (Gustafson, 2002; Van den Akker, 2003; Van Merriënboer & Martens, 2002). Second, it is generally advised to work with a project team and to develop and follow project plans (De Bie, 2003). It is further recommended to incorporate stakeholders in the project team (De Bie, 2003; Kessels, 1999; Van den Akker, 2003). Third, the tool should be useful to both novices and experts (Gustafson, 2002). Ergonomics and interface design require particular attention with regard to

usability. Guidelines and heuristics for interface design and other relevant aspects of usability can be found in Brinck, Gergle, and Wood (2002), Nielsen (2003b), Schneiderman (1998), and Smith (2001).

Method

Table 2 gives an overview of prototypes, participants, variables and methods used in the design and formative evaluation of the tool, hereafter referred to as *COMET*, which is a loose acronym for Competency Modeling Toolkit.

*** INSERT TABLE 2 ABOUT HERE ***

Participants

Participants were obtained from five different groups: internet users, Web designers, domain experts, experienced users and novice users. Internet users are people who regularly use the Internet. Web designers build professional Websites. Domain experts are knowledgeable about competence-based education and its development. Experienced and novice users are people from the target group. Experienced users have constructed at least one competence map, whereas novice users do not have such experience yet.

Participants in the formative evaluation of the first prototype, *COMET/1*, were five internet users (1 male, 4 female) and one experienced user (male). In evaluating the second prototype, *COMET/2*, participants were one Web designer (female), two internet users (1 male, 1 female), one experienced user (male), and 19 domain experts (11 male, 8 female). With the third prototype, *COMET/3*, four experienced users were involved (2 male, 2 female) and four novice users (4 females). Participants in evaluating the fourth prototype, *COMET/4*, were two experienced users (1 male, 1 female) and two novice users (1 male, 1 female). One experienced user participated in the evaluation of each of the four prototypes; all other users participated only once.

Materials

Four successive prototypes were developed, with an increasing coverage and elaboration of contents and aids. Note that the language used in *COMET* is Dutch, since *COMET* was initially developed for users in the Netherlands.

COMET/1. The first prototype, *COMET/1*, was implemented in a Website. It consisted of a

general interface, an introduction and partly the first phase in constructing competence maps: initiation. The general interface included the task manager, providing navigational facilities to switch between Web pages in general and more specifically to guide users in following the phases and steps in the right order. The introduction contained information about the use and purpose of the Website, the target group, and some background information about competence maps. Phase 1 contained an information bank and a construction kit.

COMET/2. The information bank and construction kit in phase 1 were extended. Phase 1 was further extended with a introductory and concluding part. In addition, the second prototype contained the information bank of phase 2: construction.

COMET/3. In the third prototype, the introduction was extended with information about competence in general, competence-based education, and with time investment with respect to the construction of competence maps. Information banks of phase 1 and 2 were extended as well. Compared to the second prototype the main difference was the inclusion of ten construction kit tools in phase 2. Seven of these tools were templates or procedures. The three remaining tools were paper-and-pencil versions of tools that would be transformed into “intelligent” tools in COMET/4. The paper-and-pencil tools concerned (1) the generation of a competence definition; (2) the generation of a linguistic format that is used as a template to make competence descriptions; and (3) the generation of a competence figure.

COMET/4. The fourth prototype contained all phases and all steps, including an information bank, a construction kit and a phenomenarium. The phenomenarium consisted of an example case in which an imagined project team constructed a competence map in the area of information sciences. Process descriptions as well as resulting products were provided. The example case was based on interviews with practitioners in the area of information science.

Questionnaire. The questionnaire was designed to evaluate the practicality of the prototypes on six variables: design, appeal, goal, content, confidence and relevance. Design concerns the extent to which “surface” elements of COMET such as the user interface and navigation are pleasant and easy to use. Appeal is the extent to which users like COMET and are motivated to actually use it. Goal refers to the extent to which it is clear for what purpose COMET has been designed and who should use it. Content is

the amount in which the method as implemented in COMET is clear and leads to a reliable and valid competence map. Confidence refers to the extent to which users have trust in COMET, in that it is well-thought and that it actually will help them to perform the difficult task of constructing a competence map. Finally, relevance is the degree to which COMET suits the task that users have to perform.

The variable *design* was subdivided in eight subscales: navigation, interface, usability, correction and prevention of errors, locus of control, short-term memory, text, and media. Navigation has to do with the ease to go from one Web page to another, and to find the information you are looking for. Interface refers to the consistency in and proper use of structure and color, thereby supporting the use of COMET. Usability is the extent to which COMET is easy to use, with respect to download time as well as number of steps needed to get somewhere. Correction and prevention of errors is about the way COMET prevents errors and provides information on how to correct errors. Locus of control means whether the user or the computer is “in charge” in how to use the Website. Short-term memory concerns the extent to which texts are straight-to-the-point and information users have to memorize before switching to another Web page. Text refers to the use of language, the appropriateness of text use with respect to the tone of the Website, and layout in terms of structure, contrast, typeface, color, etcetera. Media has to do with the function and appropriateness of illustrations and clips.

Subscales of *appeal* were attractiveness and motivating aspects. Attractiveness is the extent to which users liked COMET. Motivating aspects concern the extent to which COMET encouraged the user to use it.

Goal included the subscales purpose and target group. Purpose refers to what COMET does. Target groups concern COMET’s intended users.

Content was subdivided in clarity of the method, usability of the method, reliability of the method, validity of the method and support provided by the example. Clarity of the method refers to what happens in general in the phases and steps, and what the tools of the construction kit do. Usability of the method is about based on knowing what to do and when: when to take which steps, when to use which tools and when to proceed to which next step. Reliability of the method is the extent to which a competence map can be replicated over time by the same design team. Note that because COMET adapts to each situation,

different design teams are likely to design different competence maps. Validity of the method is the extent to which a competence map reflects the competencies of practitioners in a certain domain of profession. Support of the example is about the extent to which the example clarifies how to use the method.

The dependent variables *confidence* and *relevance* had no subscales. The 66 items in the questionnaire are largely based on usability questions and heuristics of Brinck, Gergle, and Wood (2002), Nielsen (2003a), Schneiderman (1998), Smith (2001) and Stoyanov (2001). Each item had to be scored on a Likert scale, ranging from 1 (“totally disagree”) to 5 (“totally agree”). Examples of items are: “The Website is easy to use” and “The text is long”. In addition, four open-ended questions were added to enable participants to comment on omissions and failures and to provide suggestions for improvement. Table 3 gives an overview of variables, subscales, and number and reliability of items.

*** INSERT TABLE 3 ABOUT HERE ***

Heuristic evaluation form I. Heuristics are usability principles or guidelines for interface design. Form I consisted of 12 heuristics for each of the sub scales of the dependent variables design, appeal and goal. The heuristics were adopted from Brinck, Gergle, and Wood (2002), Nielsen (2003a), Schneiderman (1998), and Smith (2001). The form consisted of three columns: one column naming each of the heuristics; one column for noting down comments on the heuristics, and one column for noting a grade between 1 (“total failure”) to 10 (“outstanding”), which is the normal grading scale in Dutch schools.

Heuristic evaluation form II. Form II was designed in a way similar to form I, except that the heuristics covered the sub scales of the dependent variables confidence, content and relevance. The seven heuristics were based on the definitions of the subscales. A description of the heuristics used in the evaluation forms can be found in the Appendix.

Interview format. The partially structured interview consisted of questions that were based on negative answers on the questionnaire. That is, participants who gave either a “1” on positively formulated statements or a “5” on negative statements were asked to elaborate on these scores.

Walkthrough instructions. Instructions for the walkthrough were: “Go through all pages of the Website in your own pace and manner.” With COMET/2, the participant was additionally asked to specifically pay attention to the design aspects of the Website. With COMET/4, participants were asked to

pay attention to design, appeal, goal, confidence, content and relevance.

Focus group instructions. Instructions for the 19 domain experts in the focus groups with COMET/2 (see Table 1) were: “Please comment on COMET, in particular on the confidence COMET raises with its users; the content of the Website, and the relevance of the Website for the task of making competence maps.”

Procedure

Evaluation of COMET/1. Internet users evaluated the Website through a procedure known as *heuristic evaluation* (Nielsen, 1994, 2003a, 2003b). This method is often used in iterative design processes to collect information about interface usability, by using several usability heuristics. After a short introduction to the Website and the evaluation procedure individual internet users were given ten minutes at maximum to become acquainted with the Website in their own way. Hereafter they were provided with the heuristics of form I and asked to go through the Website for a second time, evaluating the heuristics one by one. Their verbal comments were noted down by the observer, who regularly asked the participants to elaborate on their comments. In addition, the participants rated each heuristic on a scale from 1 (“total failure”) to 10 (“outstanding”). Comments and ratings were noted down on form I. Finally, participants were asked to describe problems with the Website that did not come up in the heuristics. The heuristic evaluation procedure took 30 minutes maximally. Hereafter, the participants filled out the questionnaire. The experienced user was asked to go through the Website and to fill out the questionnaire. Subsequently, an interview by telephone was conducted.

Evaluation of COMET/2. The Web designer evaluated the Website by means of a *walkthrough*. There are many ways to perform a walkthrough (Smith, 2001). In the formative evaluation of COMET, a walkthrough means that participants inspect each page of the Website and note down comments. With COMET/2, the focus was on the design aspects of the Website. Evaluations of internet users and experienced users were collected in a procedure similar to the evaluation of COMET/1. Further, two groups of domain experts (7 and 12, respectively) inspected the Website in a procedure known as a *focus group*. Here, the Website was presented to the domain experts, who were subsequently asked to reflect upon and discuss about the Website, in particular on the issues confidence, content and relevance. The

experimenter made notes of the discussion.

Evaluation of COMET/3. Individual experienced users and novice users were asked to go through the Website in their own pace (30 minutes maximally). Hereafter, they were asked to use the three paper-and-pencil tools of the construction kit. In using the tools, participants had to use a list of eight arbitrary competencies. Meanwhile, the experimenter observed and made notes of the manner of use, mistakes and faults, and of the improvements as suggested by the participants. Subsequently, participants were subjected to either a combination of questionnaire and interview, in a way similar to the evaluation of COMET/1; or a combination of heuristic evaluation and questionnaire, in a way similar to the evaluation of COMET/1 and COMET/2, except that form II was used instead of form I. All participants were asked what they would like to see in an example case.

Evaluation of COMET/4. With experienced users data were gathered by means of either a combination of a walkthrough, questionnaire and interview, or just a walkthrough and interview. The walkthrough covered all six variables. Novice users inspected the Website by means of a walkthrough, questionnaire and interview.

Analysis

From the quantitative data of the questionnaire and the heuristic evaluation forms we calculated means, standard deviations, minimum scores and maximum scores. No further analyses were conducted. Comments were used to improve the prototypes and to produce the final tool.

Results and Discussion

The quantitative results of the evaluations of the four prototypes indicated that participants were satisfied. There were no extreme values on any of the subscales, either positive or negative. Table 4 shows the quantitative results of the formative evaluation of COMET/4. These results do not represent definitive measures of COMET's practicality. Rather, Table 4 gives an impression of what may be expected from a final measurement and what aspects need to be improved. In general, participants believe that the final prototype is practical, with two exceptions. First, COMET/4 is not considered to be attractive. Second, the reliability of the method is considered to be low. Participants do not believe that a competence map made with the help of COMET will be identical to a second competence map that is constructed two months

later by the same design team, again with the help of COMET. However, the standard deviations, minimum scores and maximum scores show that participants differ greatly in their views of COMET's reliability. Thus, conclusions should be drawn with some caution and a general investigation of competence and competence maps may well be worth follow-on study.

*** INSERT TABLE 4 ABOUT HERE ***

The qualitative data were used to improve the prototypes. With respect to COMET/1, participants reported several problems and suggestions for improvement. Most comments concerned the design subscales, in particular navigation, interface, text and media. For example, some combinations of text color and background were considered sub optimal; the menu did not show in which part of the Website the user was working; and the figure showing the general method was unclear. Other comments mainly concerned the content of COMET/1, such as a lack of checklists and a supportive coach, and a too heavy focus on reading text instead of activating users to do something. The results of the evaluation of COMET/1 lead to several changes in the design of COMET/2. The general interface was considerably altered in terms of color, text and media use. The part of the task manager guiding the sequence of phases and steps was adjusted, along with some changes in the general Web structure. Finally, a checklist was added to phase 1.

With COMET/2, comments and suggestions for improvement were made with respect to the navigation subscale. Some other comments were that the Website was not very attractive, that the intended target group was not clear, and that it was not clear when a user should proceed to a next step of the method or to go back to a previous one. Also, a general overview of steps and tools was requested. Based on the results, several changes were incorporated in the design of COMET/3, in particular with respect to the structure and content of some of the steps in phase 2. In addition, for more advanced users a Web page was added providing a quick overview of phases, steps and connected tools.

Similar to the comments of COMET/1 and COMET/2, comments on COMET/3 mainly pertained to design aspects such as color use, typeface and navigation. With respect to the paper-and-pencil tools, participants reported that some words or phrases were ambiguous or unclear. In addition, they asked for procedures or guidelines that would help them to incorporate information about competencies in a competence figure. Finally, recommendations were given about the design of an example case. In the

design of COMET/4, the results of the evaluation of COMET/3 lead to some minor changes in the information bank and construction kit of the introduction, phase 1, and phase 2. The recommendations about the paper-and-pencil tools were used to make large improvements of the tools and to design “intelligent” versions of them. The recommendations about the example case were used to develop the phenomenarium.

Comments on COMET/4 mainly concerned design aspects such as inactive hyperlinks and spelling errors. There were no comments about reliability and attractiveness. The results of the evaluation of the fourth prototype were used to develop a final version of COMET. In this final version, only the spelling errors and refusing hyperlinks in COMET/4 were corrected.

General Discussion

The central research question as posed in the introduction was: What are the characteristics of a valid and practical tool that supports people conceptually as well as procedurally in constructing a competence map? First, we started with a description of the functionality of conceptual and procedural support and the supportive aids that can be used for designing the support. These analyses guided the design choices in order to obtain a valid tool. Second, the practicality of the tool was discussed. The evolutionary prototyping approach was presented and subsequently a description of the development and formative evaluation of the tool was presented. Four prototypes were developed and evaluated with intended users (both novices and experts), domain experts, internet users and Web designers.

The formative evaluation of each prototype was used to develop a subsequent, improved prototype. The results of the evaluation of COMET/4 have lead to the development of a final version of COMET. In general, most improvements concerned the design of COMET, the method and the content of the prototypes. Evaluations of the final prototype indicate that COMET is somewhat practical although perhaps deficient with regard to attractiveness and reliability.

Notwithstanding the positive results of the formative evaluations, four remarks can be made. The first one concerns differences in the *depth of exploration*. Much time was required to examine prototypes, especially COMET/3 and COMET/4. For example, COMET/4 has 88 pages, documents and tools, many of them of considerable length. Therefore, the evaluations are based on a quick review of many of the

pages, documents and tools, and only a few of them are explored in depth. Hence, ratings are not “definitive”, since participants might have given other ratings when other parts of the Website were explored by them.

A second remark concerns the differences between *manners of exploration*. Participants differ in the way they explore the prototypes, which is a logical consequence of the instructions that were given to them. One participant may read a text on one page carefully, whereas another participant may totally ignore the same page. This makes it difficult to compare ratings. Large standard deviations and large differences between minimum and maximum scores may therefore be a result of differences in exploration. Ideally, a formative evaluation should be designed in such a way that the depth and manner of explorations are fixed. Although this is not in line with the original heuristic evaluation procedure, it may be beneficial to adjust the instruction without large consequences for the quality of the heuristic evaluation.

As a third remark, an *evaluation of the final version of COMET's* is still needed, so that definitive measures of its practicality are obtained. This final evaluation should be conducted with a larger number of participants than used in the present study, and the depth and style of exploration should be kept under experimental control.

The fourth remark concerns the *validity* of the tool. Although the theoretical framework as described in the introduction is the basis of the tool's validity, it has not yet been evaluated with domain experts. In addition, one of the requirements of validity is that the components of the tool should be consistently linked to each other, which may very well be tested. Evaluations of validity may be incorporated in COMET's final evaluation.

The following sections describe the characteristics of the final version of COMET from two points of view: (1) the perspective of the user, which pertains to the practical outcomes of the present research; and (2) the perspective of the instructional designer, which pertains to the scientific outcomes of the work.

Perspective 1: the user

The first perspective is that of the user. What does the user see and do when he or she uses COMET to construct a competence map? To the user, the most important characteristic of COMET is that it does not provide predetermined solutions. Instead, COMET provides means that help users to find their

own solutions that are adaptive to the specific situation in which they are working. Thus, different users will develop different products, for example with respect to the competence definition, the way in which competencies are described, and the design of the competence figure.

COMET guides the user to generate the three parts of a competence map: competence descriptions, a competence figure, and general information. One important feature is that in the first step a personalized competence definition is generated, serving as a basis for all subsequent construction steps. In the validation phase, the competence map is validated with subject matter experts, and in the fourth phase the competence map is formally acknowledged by all stakeholders. In taking the steps, the user is supported by four types of aids: a task manager that specifies what to do when; an information bank that provides detailed textual information about performing the task at hand; a construction kit, consisting of highly specific tools that simplify tasks; and a phenomenarium, which is a case example with both process and product descriptions. The design of all types of aids were heavily based on the outcomes of the formative evaluations. Other consequences of the formative evaluations were that the interface was extensively modified; a checklist was added to each phase; a help-function was added; and an overview of phases, steps and tools was added for the benefit of advanced users.

Perspective 2: the instructional designer

The second perspective is that of the instructional designer who is involved in the development and evaluation of instructional design tools. His or her interest mainly concerns the design principles that result from developmental research. Such design principles can be formulated in the format proposed by van den Akker (1999, p. 7): “If you want to design intervention X [for the purpose/function Y in context Z], then you are best advised to give that intervention the characteristics A, B and C [substantive emphasis] and to do that via the procedures K, L and M [procedural emphasis], because of arguments P, Q and R.”.

When this format is applied to the issue of constructing competence maps, the design principles may be as following: If you want to design a tool that supports people in constructing competence maps within the context of education, then you are best advised to give that tool the following characteristics: (1) include a construction kit; (2) include a phenomenarium; (3) include a condensed information bank; and (4) include a task manager. A construction kit should be designed in such a way that it frees up processing

resources that can then be used for the problem-solving aspects of the task (Norman, 1993). A phenomenarium should provide worked examples that can be used as analogies to perform the task (e.g., Gick & Holyoak, 1980; Sweller, van Merriënboer, & Paas, 2003). An information bank should contain limited (or summarized) information about the goals of the task and additionally provide heuristics of how to take these steps (Anderson, 1985). A task manager should guide users through the design process by showing the steps to be undertaken, by guiding users in executing those steps, and by providing feedback. In general, all aids should be characterized by flexibility, in that different views on the meaning of competence are allowed and that procedures for identifying and describing competencies are applicable to all kinds of competence definitions. The present article shows that COMET in general - including the four types of aids - is acceptably practical. In addition, summative evaluations that have just been completed showed that particular aids are effective as well (Stoof, Martens, & van Merriënboer, 2004b, 2004c). Given these promising results, COMET may be a strong aid for supporting people in performing the complex task of designing competence maps that provide a good basis for the development of a competence-based curriculum.

To conclude, the evolutionary prototyping process has been described along with a process for conducting formative evaluations of a complex instructional planning tool. These processes are likely to be useful in other efforts, so apart from the particular tool that was developed, it is possible that we have contributed some knowledge about development and evaluation techniques useful in particularly complex and challenging contexts.

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39.

Table 1

Phases and Steps in Developing Competence Maps

Phase	Step	Description
Phase 1: Initiation	Define formal constraints	Mapping formal constraints as imposed by the government or national public bodies.
	Compose project team	Composing a project team that will develop the competence map.
	Make project plan	Formulating a project plan containing descriptions of the targets, planning, responsibilities and stakeholders.
Phase 2: Construction	Make competence definition	Constructing a competence definition that all team members understand and agree upon.
	Make linguistic format	Develop a linguistic format that will be used as a standardized format for describing competencies.
	Collect data	Collecting the data that will be used for identifying and formulating competencies, for example from practitioners.
	Make competence descriptions	Analyzing the data and describing competencies by using the linguistic format.
	Make competence figure	Summarize the competence descriptions in a visual representation.
Phase 3: Validation	Describe general information	Describing the goal and domain of the competence map, the definitions used, and other typical information.
	Validate competence map	Validating the competence map with for example domain experts.
Phase 4: Acknowledgement	Give feedback to competence map	Deciding if and how the competence map should be improved, based on the evaluation.
	Acknowledge competence map	Realizing a formal acknowledgement of the competence map with all stakeholders.
	Close project	Closing and eventually evaluating the project.

Table 2

Design and Formative Evaluation of COMET

Prototypes	Participants	Variables and Methods					
		Design	Appeal	Goal	Content	Confidence	Relevance
COMET/1	Internet users (<i>n</i> = 5)	HE QU	HE QU	HE QU	QU	QU	QU
	Experienced users (<i>n</i> = 1)	QU IN	QU IN	QU IN	QU IN	QU IN	QU IN
COMET/2	Web designers (<i>n</i> = 1)	WA					
	Internet users (<i>n</i> = 2)	HE QU	HE QU	HE QU	QU	QU	QU
	Experienced users (<i>n</i> = 1)	QU IN	QU IN	QU IN	QU IN	QU IN	QU IN
	Domain experts (<i>n</i> = 19)				FG	FG	FG
COMET/3	Experienced users (<i>n</i> = 2)	QU IN	QU IN	QU IN	QU IN	QU IN	QU IN
	Novice users (<i>n</i> = 2)	QU IN	QU IN	QU IN	QU IN	QU IN	QU IN
	Experienced users (<i>n</i> = 2)	QU	QU	QU	HE QU	HE QU	HE QU
	Novice users (<i>n</i> = 2)	QU	QU	QU	HE QU	HE QU	HE QU
COMET/4	Experienced users (<i>n</i> = 1)	WA QU IN	WA QU IN	WA QU IN	WA QU IN	WA QU IN	WA QU IN
	Experienced users (<i>n</i> = 1)	WA IN	WA IN	WA IN	WA IN	WA IN	WA IN
	Novice users (<i>n</i> = 2)	WA QU IN	WA QU IN	WA QU IN	WA QU IN	WA QU IN	WA QU IN

Note. HE = heuristic evaluation; QU = questionnaire; IN = interview; WA = walkthrough; FG = focus group.

Table 3

Variables, Sub Scales, Instruments and Internal Consistency

Variables	Sub scales	Questionnaire		Heuristic evaluation I	Heuristic evaluation II
		# items	Cronbach's α	# items	# items
Design	Navigation	4	.62	1	
	Interface	7	.70	1	
	Usability	5	.73	1	
	Correction and prevention of errors ^a	2	.62	1	
	Locus of control ^b	2	.83	1	
	Short-term memory	3	.64	1	
	Text	9	.76	1	
	Media	2	.52	1	
Appeal	Attractiveness	1	-	1	
	Motivating aspects ^c	3	.68	1	
Goal	Purpose	1	-	1	
	Target group	1	-	1	
Content	Clarity method	4	.67		1
	Usability method	4	.93		1
	Reliability method	1	-		1
	Validity method	2	.68		1
	Support example	5	.73		1
Confidence	-	6	.75		1
Relevance	-	4	.84		1
		Σ 66		Σ 12	Σ 7

^a Two items were excluded in order to enhance the scale's internal consistency.

^b Two items were excluded.

^c One item was excluded.

Table 4

Formative Evaluation COMET/4

	Subscale	<i>n</i>	<i>M</i>	<i>SD</i>	Min.	Max.
			Questionnaire			
Design	Navigation	3	4.17	1.01	3.00	4.75
	Interface	3	3.71	0.14	3.57	3.86
	Usability	3	4.07	0.61	3.40	4.60
	Correction and prevention of errors	3	3.00	1.00	2.00	4.00
	Locus of control	3	4.00	1.00	3.00	5.00
	Short term memory	3	3.22	0.77	2.33	3.67
	Text	3	3.41	0.45	2.89	3.67
	Media	3	3.33	1.26	2.00	4.50
Appeal	Attractiveness	3	2.33	1.16	1.00	3.00
	Motivating aspects	3	3.56	0.39	3.33	4.00
Goal	Purpose	3	5.00	0.00	5.00	5.00
	Target group	3	5.00	0.00	4.17	5.00
Content	Clarity method	3	3.83	0.58	3.75	4.50
	Usability method	3	4.50	0.66	2.00	5.00
	Reliability method	3	2.67	1.53	1.00	4.00
	Validity method	3	4.00	0.50	3.50	4.50
	Example	3	3.53	0.23	3.40	3.80
Confidence	Confidence	3	4.50	0.29	3.50	4.67
Relevance	Relevance	3	4.83	0.14	4.75	5.00

Note. The scale ranges from 1 to 5 (“totally disagree” to “totally agree”), on a positively formulated statement.

Appendix

Heuristics in the Formative Evaluations

Heuristic	Description
<i>Heuristic evaluation form I</i>	
1. Navigation	The structure of the Website should be clear. Users have to know where they are and how to come somewhere else. Users have to be able to find the information they are looking for easily.
2. Interface	The interface should be simple and consistent. The structure of the interface and the color use should match with the content and “tone” of the Website. The structure has to support the use of the Website.
3. Usability	Users quickly should know how to use the Website. The Website should be easy to use. Pages should be downloaded quickly. Users should not have to perform to many actions to reach intended information.
4. Correction and prevention of errors	Errors should be prevented. If a users makes a mistake he or she should receive feedback and to be able to undo errors quickly.
5. Locus of control	Users should have the feeling that they decide what is happening rather than the Website.
6. Short term memory	Pages should not be too long or contain too much or redundant information. The Website cannot request that the user remembers information when navigating to another page.
7. Text	The text should be pleasant to read with respect to paragraphs, use of white lines, color, contrast and typeface. The language should be in accordance with the user and it should be clear and direct. Texts should be not too long and should have a beginning, middle section and end.
8. Media	Media (illustration, clips, etc.) should fit the content of the Website and have a clear function.
9. Attractiveness	The Website should look nice.
10. Motivating aspects	The Website should motivate users to use it.
11. Purpose	The purpose of the Website should be clear.
12. Target group	It should be clear who are the intended users of the Website.
<i>Heuristic evaluation form II</i>	
1. Clarity method	The method should be clear. The user should quickly know how to use the method. It should be clear what happens in the steps and phases. The tools of the construction kit should be clear.
2. Usability method	The method should be usable. The user should know exactly what to do every time. It should be clear when the user has to go to a next step or phase, and at what time tools should be used.
3. Reliability method	The method should lead to a reliable competence map. When a user makes a competence map, a second one constructed 3 months later should be similar.
4. Validity method	The method should lead to a valid competence map. The competence map should be a good reflection of the competencies practitioners need in a certain domain of profession.

- 5. Support example The example should make clear how to use the method. The example should be clear.
 - 6. Confidence The Website should raise confidence with the user. The user should have the impression that the Website is constructed carefully. De Website should look professional.
 - 7. Relevance The method should be relevant. The method should fit to the task of constructing a competence map in practice. People who build a competence map should gain from the method.
-