Expert Concept Mapping Method for Defining the Characteristics of Adaptive E-Learning: ALFANET Project Case

☐ Slavi Stoyanov
Paul Kirschner

The article presents empirical evidence for the effectiveness and efficiency of a modified version of Trochim's (1989a, b) concept mapping approach to define the characteristics of an adaptive learning environment. The effectiveness and the efficiency of the method are attributed to the support that it provides in terms of elicitation, sharing, reflection and representation of knowledge. It produced valuable results in a very short time as compared to classical techniques such as questionnaires and interviews. The interpretation of data suggests some theoretical considerations and practical solutions for the design and development of an adaptive e-learning environment. The research also points to a number of ways to improve the technique in terms of time for discussing ideas, visualization, and explicit support for generating unconventional ideas.

☐ An *adaptive e-learning environment* is an interactive system that personalizes and adapts e-learning content, pedagogical models, and interactions between participants in the environment to meet the individual needs and preferences of users if and when they arise. The adaptation entails presenting different structured e-learning resources in a variety of ways including, when appropriate, advice on using the material available.

The first step in designing adaptive e-learning is to define what adaptive learning means in the context of an e-learning environment. A popular approach in the modern software design paradigm (Arlow & Neustadt, 2001; Constantine, 2001; Constantine & Lockwood, 1999; Larman, 2001) requires asking users what they want. It suggests using interviews and questionnaires for collecting the needed information. Apart from the eventual users (learners and instructors), experts in the domain of e-learning such as researchers, software designers, and developers are also an important target group when defining characteristics of adaptive e-learning environments. This is especially the case when prospective users do not have much experience, which was the case with the Active Learning for Adaptive Internet (ALFANET) project.

Research on expert-novice differences in dealing with complex tasks, of which designing an adaptive e-learning environment is an example, suggests that experts can more reliably interpret information and come up with new ideas than can nonexperts (Eysenck & Keane, 2000; Van Merriënboer, 1997). Expert focus

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groups are seen as a powerful source for collecting broad and deep information (Patton, 1990). It is often the case, however, that experts look at the problem from different perspectives and, therefore, present conflicting approaches (Schön, 1996). On the one hand, such multiple perspectives can provide a broad view on the issue at hand. On the other hand, they can provoke defensive tension within the group, which might lead to disappointing final results (Voss, Lawrence, & Engle, 1992). Providing specific support for these discussions can help manage such situations. Recent developments of design methodologies in domains such as training (Kessels, 1999; Kirschner, Carr, van Merriënboer, & Sloep, 2002; Visscher-Voerman, Gustafson, & Plomp, 1999), software (Arlow & Neustadt, 2001; Constantine, 2001; Constantine & Lockwood, 1999; Larman, 2001), strategic management (Hodgson, 1999;Van der Heijden & Eden, 1998; Vennix, 1997), and engineering (Cross, 2000) recognize this need of involving experts in a structured and facilitated process of discussion so as to make use of their unique knowledge, skills, and experience. In this article, we discuss and test the effectiveness and efficiency of a specific method to facilitate e-learning experts in describing what they consider to be the necessary features of an adaptive e-learning environment.

We modified Trochim's concept mapping approach (1989a,b; 1996; 1999a,b; see also Jackson & Trochim, 2002; Concept System, 2002) by incorporating the brainwriting-pool technique (VanGundy, 1997), the Post-it® Notes problem-solving procedure (Straker, 1997), the Delphi approach (VanGundy, 1997), and expert focus groups (Patton, 1990). Trochim's concept mapping method was used as the basis because it provides a user-friendly platform for structuring the discussion of a group of informed people while triangulating multiple perspectives on a topic of common interest in order to describe their ideas and consolidate mutual understanding about a specific issue. Trochim (1999b) claimed that his method was different from other mapping approaches such as classical concept mapping (Novak, 1998), cognitive mapping (Eden & Ackermann, 2002; Eden, Ackerman, & Cropper, 1997), mind mapping (Buzan & Buzan, 1996), and solution, mapping, interactive, learning, environment (SMILE) mapping (Stoyanov, 2001), in a number of substantial ways. First, Trochim's approach can aggregate the individual contributions of group members into a final group product by applying a specific algorithm. Second, it develops a meaningful Euclidean framework to depict the relationships between ideas, where the distance between symbols is interpreted as an empirical estimate of the semantic distance between ideas. Third, it uses a simple and intuitive facilitated approach, in which specific steps are planned by a facilitator to support participants in articulating their ideas while performing common and familiar activities such as brainstorming, sorting, and rating. Finally, it applies powerful statistical procedures, such as multidimensional scaling and hierarchical cluster analysis, for the data.

Despite these differences, Trochim's approach (1989a,b; 1996; 1999a,b) also has a number of similarities with the mapping approaches referred to. It (a) allows individuals' cognitive realities about a specific issue to be made explicit, (b) can represent the relative importance of the ideas in a spatial format, and (c) can show the relationships between different, individually produced items. It is also compatible with other classical methods for collecting information, such as interviews and questionnaires, but adds value by imposing an overarching seamless strategy. The method is similar to an expert focus-group interview, but instead of asking questions and obtaining answers, experts describe their ideas in a structured way while working as a team.

The article addresses two specific research questions:

1. How might this method facilitate experts in producing *effective* and *efficient* problem solutions in the domain of e-learning?
2. What are the characteristics of adaptive e-learning environment according to an expert concept mapping approach?

To address the first research question, we need to define what is meant by the effectiveness and the efficiency of problem solutions. We define effectiveness as a function of (a) *production*—number of suggestions made, (b) *comprehensiveness*—the extent to which suggestions are representative for the current practice in learning management systems (LMS), and (c) *elaboration*—the extent to which the suggestions are contributions to current theory and practice of designing e-learning environments. To determine a base-line for the first indicator of effectiveness, *number of statements*, we compare the number of ideas generated within the framework of the current concept mapping study with the quantity of statements produced in the framework of Trochim's other projects, involving between 10 and 15 participants. These projects are all similar to the ALFANET project in the attempt to provide solutions to ill-structured problems. We chose a benchmark equal to the highest score that the other concept mapping projects had achieved, namely 132 statements (SenGupta, 1996). We expect that using diverse problem solving techniques within Trochim's (1989a, 1999b) methodology will result in more statements than the benchmark.

The second indicator of effectiveness, comprehensiveness, predicts that the ideas will be in accordance with the results of representative contemporary research on best practice in LMS. We compare the results of the current study with the standards developed by the Learning Management Systems Survey (Brandon-Hall.com, 2002), a meta-analysis providing comparative information on 29 commercially available LMS and 68 vendors of such systems. The methodology includes vendor questionnaire and on-line or in-person demonstrations of products by primary and secondary reviewers. The survey identified as benchmarks the following aspects of LMS: learning management, content development, testing and assessment, collaboration, classroom training management, management and administration, and technology.

The third indicator for effectiveness, elaboration, refers to the expectation that the current concept mapping research will spark some insights for further exploration in addition to those within the benchmarks. We expect this study to operationally define adaptive and active e-learning and to suggest ideas for relevant instructional support.

Efficiency is based on the time spent to achieve the just described quantitative and qualitative results, as compared to other techniques such as interviews and questionnaires. For comparison we used the survey that the ALFANET project itself applied to determine user requirements for an adaptive LMS. This survey—using interviews and questionnaire—took three months. The earlier discussed Learning Management Systems Survey (Brandon-Hall.com, 2002) took six months. We expected the current study to produce valuable results within a much shorter period, approximately one week, including analysis.

The second research question is related to the values of comprehensiveness and elaboration discussed above. The characteristics of adaptive e-learning are determined according to groups of statements identified and their relative importance after sorting, rating, and cluster analysis of those groups. We expect that concept mapping data will support defining the most substantial features of electronic learning environment for active and adaptive learning.

METHOD

The study here can be defined as *process development research* (Richey & Nelson, 1996). This type of research investigates the whole or the part of the process of design, development, and evaluation of an instructional product. A development research project addresses a context-specific problem situation to determine the characteristics of what is going to be developed along with attempting to understand and improve the design process and designer problem solving by developing new tools and techniques. The current study aims to gather "evidence of the validity and/or effectiveness of a particular technique or model; conditions and procedures that facilitate the successful use of a particular technique or model; and explanations of the successes or failures encountered in using a particular technique or model" (Richey & Nelson, p. 1229) and is, as such, process development research. Within the framework of the development research paradigm, concept mapping is seen as a research tool for solving a specific design problem in the context of developing an artifact, here an adaptive e-learning environment for active learning. The study takes the form of an *exploratory case study* (Krathwohl, 1993; Yin, 1994) with *retrospective analysis* (Richey & Nelson). We did not begin with any propositions concerning adaptive e-learning. We explored the issue by providing conditions that facilitated the discussion of a group of experts. We then analyzed the results, trying to develop some explanations of what happened. The sample is formed, as is most of the development research project, out of the population of designers, developers, and instructors.

Participants

From the Educational Technology Expertise Center at the Open University of the Netherlands, 30 experts were invited to take part in this research; 12 responded positively. They were joined by 2 experts from the Department of Computer Science at that university. The experts are specialists in the domain of educational technology, representing three different institutional programs; namely, research, development, and implementation. The mission of the *research program* is to conduct research in the domain of analysis, design, delivery, and assessment of competency-based learning in higher education. The *development program* is focused on developing standards for systems for education and training. The *implementation program* supports faculties at the university and external clients (high schools, polytechnics, universities and companies) in solving educational and training problems and applying the solutions developed in the Educational Technology Expertise Center to design and development of instruction. Of the experts, 8 had a position equivalent to assistant professor; 4, associate professor; and 2, full professor. Participating in the research were 3 female and 11 male experts.

Experts taking part in this study have rich and diverse experience in one or more of the following areas: research on competency-based learning; design and development of LMS; architecture of computer systems; evaluation studies on student experience in using electronic learning environment; teaching through different types of LMS; and daily contact with students, instructors, designers, system administrators, and programmers.

Procedure

The procedure consisted of four phases: (a) introduction, (b) idea generation, (c) sorting statements, and (d) rating statements. Participants were first introduced to the ALFANET project itself, to the purpose of this small-scale research in relation to the project, and to the approach applied. Idea generation began with a brainstorming session. In order to enhance the elicitation of expert ideas about the characteristics of an LMS we combined classical brainstorming with techniques such as brainwriting pool and gallery method (VanGundy, 1997), and Post-it® Notes problem-solving (Straker, 1997). The idea generation itself started with a trigger statement, to stimulate the experts to think about the needs of the main users of an adaptive LMS. We suggested an action-oriented format for the statements, indicating the interaction of users with the system and between users themselves. The trigger statement took the following form: "Given an adaptive LMS, {the users: learners, instructors, system administrators, programmers . . .} should be able to {action: support, analyze, design, change, adapt, receive, assess, build, provide . . .} an {object: prior knowledge, fellow students, gaps in their knowledge, success, . . .}." For example: "Given an adaptive LMS, the learners should be able to identify their level of knowledge, learning styles, and learning locus of control."

The format of the trigger statement was different from Trochim's (1989a, 1999b) concept mapping approach. He provided only guidelines for the participants (e.g., make it action oriented, suggest a time frame, keep it brief, word it as instruction). Some examples taken from Trochim's project are: What are the competencies that a consultant needs in order to do business reengineering? and Describe specific things we could observe that would indicate that creativity is occurring in our organization. The trigger statement of the ALFANET concept mapping approach reflects the well established practice of behaviorally formulating learning objectives (Mager, 1997) and the universal structure of activity including conditions, subject, action, and object (Vygotsky, 1978; see also Jonassen, 2000). It is action oriented, specific, brief, and comprehensive.

Experts were then invited to brainstorm individually and write down their ideas on Post-it® Notes, respecting the rules of brainstorming. They were stimulated to refer not only to their experience of what is but also to what should be about an LMS. After this initial 10-min period of individual brainstorming, the participants were asked to pick up one of their notes and put it in the middle of the table, round-robin fashion, while telling the others what the statement was. Waiting their turn again, participants were able to generate new ideas, inspired by the suggestions of others. This phase took about 2 hr and produced 202 ideas. Then some elements of the Delphi method were applied as the facilitator checked all statements for repetitions as well as for possible combinations. The revised version of 88 statements with identification numbers from 1 to 88 was sent back to the experts for sorting and rating 2 days later. Within the given circumstances of the ALFANET project, sorting and rating appeared more effective and efficient than the original requirements of the Delphi method, which makes use of several rounds of exchanging materials between facilitator and participants.

For sorting and rating, the experts were provided with the original templates of Trochim's concept mapping method (Concept System, 2002). Sorting was carried out in two steps. Step One required the participants individually to (a) group the statements for similarity in meaning, (b) arrange them in a way that feels best (there is no right or wrong grouping), (c) place each statement into one group only, (d) place each statement somewhere, and (e) place a single statement in its own group if it is unrelated (in the participant's opinion) to the other statements.

Step Two required the participants individually to (a) pick up any one group of statements and write down a short phrase or title describing the content of the group, (b) write the identification numbers that are included in that particular group under the word or phrase, and (c) continue in this way until all groups have been named and the identification numbers of their constituent statements have been recorded.

Finally, for the rating procedure, the experts were asked to rate each of the 88 statements on a 5-point scale of emphasis where 1 meant that the statement should be given relatively *little* emphasis in developing an LMS prototype and 5 meant that the statement should be given *extremely high* emphasis.

The different elements of the procedure used are meant to facilitate different aspects of defining the characteristics of adaptive e-learning as an ill-structured problem. As stated, the brainstorming and trigger statements were aimed at facilitating knowledge elicitation, creation of ideas, and projecting thinking toward what should be in addition to what is. The announcing of statements was intended to increase sharing and representing of ideas. The sorting and rating of the statements were intended to stimulate reflection. The effectiveness and the efficiency of the solutions based on the ALFANET concept mapping method depend on these processes of knowledge eliciting, sharing, representing, and reflecting.

RESULTS

Analysis of the Method

The analysis involves multidimensional scaling of unstructured sort data, a hierarchical cluster analysis, and the computation of average ratings for each statement and cluster of statements (Trochim, 1989a, 1999a, 1999b). The analysis begins with the building of an $N \times N$ (where N is the total number of statements) binary symmetric matrix of similarities ($S_{N \times N}$) for each participant from the sorting data. For any two statements i and j, 1 is entered in S_{ij} if the two statements are placed in the same pile by the participant, otherwise 0 is put in the cell. The total $T_{N \times N}$ similarity matrix is built by summing across the individual $S_{N \times N}$ matrices. Any cell of this matrix can take integer values between 0 and M, where M is the total number of participants who sorted the statements. The total similarity matrix, $T_{N \times N}$ is raw structure data for the multidimensional scaling analysis. It produces a two-dimensional $X_{N\times 2}$ configuration (point map) of the set of N statements based on the criteria that statements piled together most often are more proximately located in a two-dimensional space while those grouped together less often are more separate from each other. Based on traditional estimates of reliability, Trochim (1993) constructed specific reliability estimates for concept mapping data. He reported strong positive split-half total matrix and map reliabilities, and average individual-to-total, individual-to-map, individual-to-individual, and rating-to-rating reliabilities.

Citing a work of Kruskal and Wish (1978), Trochim (1999b) argued that two-dimensional solutions of multidimensional scaling are easier to apply than three or more dimensions, and more desirable when clustering results need to be displayed. Multidimensional scaling generates a rather detailed point map, which the current version of SPSS® package (SPSS, version 11.0.1, 2002) makes difficult to visualize and read, especially when a great number of items is produced. The results of the multidimensional scaling were used as input data for a hierarchical cluster analysis, which provided a more global picture transforming the point map into nonoverlapping clusters. The number of clusters was identified by taking vertical slices at different heights of the cluster tree. There is not a simple mathematical criterion for selecting the number of clusters. Trochim's approach favors first examining the maximum possible options before going down the tree to reduce the cluster solutions. This process always involves judgment and interpretation. Rating data provides a third dimension of the data. We used Inspiration® software (Inspiration, version 6.0, 2002) for visualizing the results of this analysis.

Analysis of the Ideas Generated

As was stated, a hierarchical cluster analysis of the raw data was carried out to identify how experts classified statements into groups. In addition, means were attached to each statement and group of statements. The data are presented in the Appendix. The analysis distinguishes the following 17 clusters of items:

1. *Learner-led adaptation.* Learners should be able to find both what they want to learn and how they want to learn it. Specifically, learners should be able to match their learning to their abilities, level of prior knowledge, and learning style.

2. *Learner-regulated studying.* This cluster represents learner locus-of-control in learning. Learners should be able to define their own learning objectives, select a set of learning tasks, plan their study, and regulate their learning tempo.

3. *Learner self-management.* This cluster refers to the possibilities for learners to manage their own learning. They can see where they are in the curriculum or competence map and what learning task or activity to carry out next, consult course-tracking data, and monitor their learning. They have an opportunity to prebrowse and search for learning content.

4. *Planning of learning.* This cluster emphasizes the opportunities that the instructors and the system provide for learners to select what to follow next and to plan learning based on feedback that they receive.

5. *Learner auditing.* According to experts, learners should have possibilities to test the level of their knowledge and learning styles, and to be able to see their learning results.

6. *System administration and management.* This cluster relates to registration of users, tracking of learner progress, reporting of dropout rate, and providing statistics on learning results. The system should have options for providing managers with an overview of learner study progress. Institutions providing e-learning should be able to certify the level of education. System administrators should provide a high-quality "helpdesk."

7. *Technical standards.* An LMS should be compliant with international technical standards. While it stores learner dossiers and portfolios, it must ensure security, privacy and confidentiality. An LMS organizes a repository of learning objects as metadata. An interesting suggestion is providing visually handicapped users with alternative opportunities.

8. *Instructor support.* Experts suggest a per-

formance support system to help instructors in analysis, design, and evaluation of training. This includes authoring tools to assist in designing personalized learning environment; that is, selecting, adapting and reworking content from a library of reusable learning objects. Experts agreed fully on the idea of allowing a variety of pedagogical models.

9. *Instructor-led adaptation.* Experts, while stressing learner-centered adaptation opportunities, also stress the ability of instructors to adapt learning tasks to learners' personal constructs. Instructors should be allowed to adapt content to existing knowledge, skills, and learning styles and have possibilities to offer different educational scenarios for different types of learners. Experts also promote the possibility for an LMS to dynamically adapt learning tasks to learner characteristics and performance, a major goal of the ALFANET project.

10. *Assessment.* This includes statements related to the evaluation of learner achievement. Instructors assess learner knowledge and skills (via traditional and alternative assessment forms, such as peer assessment and learner portfolios) as well as monitor and analyze learning progress. However, the cluster also contains statements reflecting not only learning results, but also goals as well, suggesting a link between what *should* be learned and *how much* has been learned. Finally, an LMS should allow for evaluating the extent to which instruction was successful.

11. *Instructor-regulated studying.* Experts also emphasize the need for instructor locus-of-control of learning situations. This group includes instructors being able to determine learning tasks, provide feedback to learners, aid learners to improve their learning, and provide guidance.

12. *Performance support for learners.* Experts identify the need for embedded support for learner performance. Learners should have access to resources and get just-in-time, just-enough and at-the-point-of-need support. The idea firmly established in corporate training might be useful if modified for the purposes of competency-based higher education with its orientation toward solving complex tasks.

13. *Administrative communication.* A number of statements identify communication possibilities in an LMS. Hierarchical analysis distinguishes between two communication clusters. This one involves the interaction of the system with users for administrative purposes.

14. *Learning communication.* This second communication cluster emphasizes interaction between learners and instructors. An LMS should support instructor-learner, instructor-instructor, and learner-learner communication.

15. *Collaboration.* Statements related to organizing, structuring, and moderating group work among learners form a special cluster. Instructors should be able to use different modes of group discussion and be able to collaborate with learners synchronously on group learning tasks. Experts also emphasize the possibilities of peer learning.

16. *Group and individual work.* There are a few statements emphasizing support for both individual and group learning activities. Special attention is paid to project work.

17. *Socialization.* Experts underline the need for an LMS to provide a social context for learning and professional socialization of learners. This is an idea related to the concepts of social learning and cognitive apprenticeship.

A second round of cluster analysis revealed that the 17 clusters could be formed into four more global groups, namely (a) learner-centered support, (b) instructor-centered support, (c) collaboration and communication, and (d) administration and management (see Figure 1). These four clusters can be seen as the main issues to address when designing e-learning environment.

Learner-centered support includes learner-led adaptation, learner-regulated studying, learner self-management, planning of learning, and learner auditing. All of these have to do with how learners can better plan and carry out their learning. The clusters instructor support, instructor-led adaptation, assessment, instructor-regulated study and performance support for learners constitute the second global group, *instructor-centered support.* Here the clusters of statements relate to how the system can best support the teacher or institution with respect to student learning. *Collaboration and communication* subsumes the clusters administrative communication, learning communication, collaboration, individual and group work, and socialization. This general cluster deals with aspects of the LMS that relate to the social and communicative functions considered to be necessary for effective and efficient learning. Finally, the global cluster *administration and management* includes the clusters of system administration and management, and technical standards.

At first glance the cluster planning of learning did not seem to fit well with other clusters in the learner-centered-support group of clusters. Two out of the three statements in this cluster refer to the roles of instructors and system, instead of learners. It might suggest that hierarchical cluster analysis sometimes generates inconsistent data. However, a closer look reveals that the two statements reflect activities quite similar to those of the statements in the learner self-management cluster, but the emphasis is put on the opportunities that both instructors and the system create for learners to plan their learning.

Analysis of the Emphasis (to Be) Given

Rating of the statements according to how much emphasis should be attributed (see the Appendix) suggests some ideas for designing an LMS. The list of the first 10 most highly rated statements (see Table 1) includes statements that are representative for all clusters, but with a focus on instructional design issues. A combination of them describes a simple scenario. Using an LMS that inherits opportunities for a variety of pedagogical models, instructors are supported to design a project-based learning environment, which produces authentic situations containing a set of realistic complex learning tasks for learners to accomplish. Having this learning situation, an instructor creates different pedagogic models for different types of learners and

Figure 1 ☐ Grouped clusters with means.

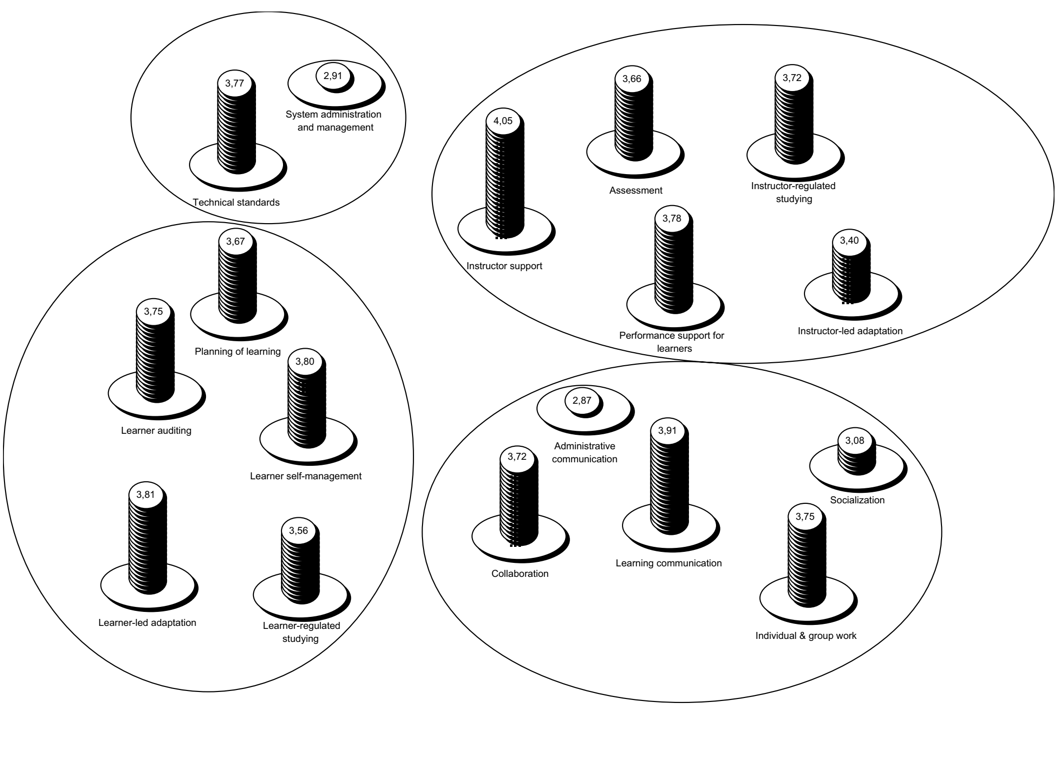

Table 1 □ The ten most important characteristics of a learning management system (LMS).

Statement	Mean
1. Instructors should be able to create (design) new learning materials	4.375
2. Learners should be able to get quick access to resources that support job performance	4.375
3. Learners should be able to receive help just when they need it	4.375
4. Learners should be able to work on projects	4.375
5. Instructors should be able to offer different didactic scenarios for different types of learners	4.250
6. Instructors should be able to get support on developing instructional materials	4.250
7. An LMS should allow variety of pedagogical models	4.250
8. Instructors should be able to provide feedback to learners	4.250
9. Learners should be able to see their learning results	4.250
10. Learners should be able to communicate with other learners	4.250

learner roles. Working on learning tasks, students get just-in-time, just-enough, and at-the-point-of-need support in terms of reference information, coaching, and feedback, and they collaborate with other learners.

DISCUSSION

The data provide direct evidence for the effectiveness and efficiency of the method. The 202 statements generated by the experts were approximately twice the reported average number of statements in other projects applying Trochim's concept mapping approach (Trochim, 1989a, 1996, 1999a), and 1.5 times the highest reported score on this indicator, the 132 statements chosen as benchmark (SenGupta, 1996). Enriching the classical brainstorming method with other techniques clearly made the elicitation process more effective.

Further, the statements were generated within less than two hours, which was indicative of the efficiency of this method. Another indicator for the efficiency of the approach was the fact that the whole study was completed within a week, a fraction of the time that conventional techniques such as interviews and questionnaires often take (e.g., at least three months needed in the ALFANET project, 2002, and six months reported in the Learning Management Systems Survey, Brandon-Hall.com, 2002).

The groups of clusters that the cluster analysis identifies cover the main points of the benchmarks established by a representative survey of LMS best practices (Brandon-Hall.com, 2002) namely, learning management, content development, classroom training management, collaboration, management and administration, and technology. This can be seen as evidence for the effectiveness of the expert concept mapping method, applying the indicator of comprehensiveness. The study does not provide enough detail as to management and administration, technology, and classroom training management. However, the current concept mapping project brings some insights that go beyond the current theory and practice of designing e-learning environments, which is an indicator for elaboration. At a general, methodological level, the data suggest a conceptual framework that prevents one-sided thinking of the issues related to designing of e-learning environments. Dimensions of this framework are individual versus group work; learner versus instructor learning locus of control; learner versus system determined adaptation; asynchronous learning and instruction versus synchronous learning and instruction; monitoring and tracking learning versus respecting privacy and confidentiality.

At a more operational level, the study outlines the main characteristics of an instructional design approach for active and adaptive e-learning with concrete suggestions for practice.

The cluster analysis of statements explicitly generates a framework for defining the concept of adaptation. It consists of the following conceptual continuums: preassessment versus monitoring adaptation; system-centered versus learner-centered adaptation; single versus multiple adaptation; and preferential versus developmental adaptation.

The bipolar look of the concepts does not suggest mutually exclusive (neither-nor) hypotheses.

Preassessment versus monitoring adaptation

An adaptive e-learning environment should propose opportunities for preassessment of different personal constructs, for example, through tests or check-lists for knowledge, and questionnaires for learning styles and learning locus of control. Based on a personal profile, the user receives suggestions of what and how to study. This prespecified adaptation could coexist with dynamically adapting instruction while tracking learner behavior. Most current theory and practice in e-learning suggests either preassessment or monitoring adaptation, but rarely a combination.

System-centered versus learner-centered adaptation

Both preassessment and monitoring are system-centered forms of adaptation. Learner-centered adaptation refers to providing learners with possibilities to select options available in the learning environment for accommodating personal constructs themselves. For example, learning content can be presented at different levels of difficulty within a configuration of different instructional objects such as background information, examples, procedures and practice. Learners are free to decide where to begin in constructing a specific pattern of instructional objects and a content level (Stoyanov, 2001).

Single versus multiple adaptation

The results suggest an orientation toward multiple adaptation, which is in accordance with the findings and conclusions discussed in the literature on individual differences (Ayersman & von Midden, 1995; Honey & Mumford, 1992; Jonassen & Grabowski, 1993; Keirsey & Bates, 1998; Kirton, 1994; Kolb, 1998; Riding & Rayners, 1998). Most existing solutions in the domain of adaptive learning match instruction to one individual construct, such as level of prior knowledge, and to a lesser extent, to learning styles. It is not feasible, however, to deal with all reported individual constructs such as abilities, cognitive styles, learning styles, prior knowledge, locus of control, personality traits, and achievement motivation. One possible solution of this complex issue is to consider learning styles as multilayer integrative constructs having both cognitive and personality trait dimensions. In this case, adaptation concerns knowledge, learning styles and learning locus of control, which is a manageable instructional design task (Stoyanov, 2001).

Preferential versus developmental adaptation

Expert concept mapping research can help set the agenda for exploring adaptation, not only to user preference, but also to developing their weak characteristics so as help the learner become more versatile. Salomon (1979) first discussed this issue in the context of the trait-treatment interaction functions, questioning whether the preferred strategy was also the best strategy. Clark (1983) expanded on this idea by positing that adherence to the preferred style or strategy could even be mathemathantic (Greek: *mathema* = learning, *thanatos* = death). Jonassen and Grabowski (1993) argued that people are capable to learn a learning strategy that is less congenial to their learning styles, but is more effective for a particular task.

Apart from exploring adaptation, this study also generated ideas on active learning—another important concept in the ALFANET project. Experts propose an interesting combination of the whole task practice (van Merriënboer, 1997; van Merriënboer, Clark, & de Croock, 2002) and performance support system approaches (Bastiaens, Nijhof, Streumer, & Abma, 1997a, 1997b; Gery, 1995; Raybould, 2000). Instruction is organized around practicing whole learning tasks (e.g., vignettes, cases, scenarios, projects) that may represent different problem formats (e.g., worked-out examples, completion problems, conventional problems). For each problem format, relevant just-in-time, just-enough and at-the-point-of-need learning support is prescribed providing both constituting knowledge and systematic problem solving skills. The data suggest not only *what* support should be given, but also *who* could or should give the support. In addition to instructors, external experts and peers could be involved in the professional socialization of learners—an idea related to the concept of social scaffolding (Bandura, 1986; Vygotsky, 1978) and community of practice (Lave & Wenger, 1990).

Although this study provided a comprehensive description of adaptive and active e-learning environment, it failed to explicitly consider the concept of intelligent software agents. Intelligent agents were introduced as a very important concept in the context of the ALFANET project, and as such were expected to be part of the analysis. This proved not to be the case. A possible reason might be the trigger statement, which emphasizes human agents. One would expect, however, the concept of software agent to emerge during free association on topics related to adaptive e-learning environments where the focus is on intelligent agents. The fact that it was not explicitly referred to may be interpreted as a warning against the uncritical introduction of agents just because the concept is appealing. This should not be considered as skepticism, but rather as realistic vision based on the theory and practice of intelligent agents for educational and training purposes. There have been so many models and very few applications. Also, it could be the case that experts are reluctant to accept anything that is perceived as replacing them. The research and practice of experts systems documents this attitude very well.

Intelligent agents, without a doubt, could be useful for an adaptive learning environment. They also could be considered a stimulus for bringing learning theory to new horizons. However, the role of agents should be very carefully defined in terms of why we need them, what services they could provide, what type of control they could exert, how realistic their design is, and how feasible their development is for a learning environment.

CONCLUSION

The concept mapping method in this study proved effective and efficient for defining the characteristics of an adaptive e-learning environment. The results are in accordance with the main findings of representative surveys for the best practices in this domain. In addition, the method provided some innovative ideas on instructional design for adaptive and active learning, developing operational definitions of adaptive and active e-learning that can be further transformed into design solutions. The approach supported the efforts of defining the main characteristics of an adaptive e-learning environment in a very short period of time. The method proved that "less can be more" and improves Trochim's (1989a, 1999b) concept mapping method by changing the format of the trigger statement and introducing more and diverse techniques for idea generation.

In general, the effectiveness and efficiency of the concept mapping method are due to the systematic facilitation of experts' knowledge eliciting, sharing, representing, and reflecting. This research provided a ground to predict that such a method would be effective, efficient, and attractive for the next stage of the conceptual design when concepts are transformed into design solutions. Perhaps the process of eliciting, sharing, representing, and reflecting could be facilitated by other techniques relevant to the tasks that have to be accomplished at this stage. Scenarios (Carroll, 2000; van der Heijden, 1996) and hexagon mapping (Hodgson, 1999) are believed to be appropriate techniques for these purposes.

Ideally, special software (Concept System, 2002) for Trochim's concept mapping method should be used. In practice it was impossible for us to get it in time. We chose to follow the logic and procedure of the method and apply conventional tools such as SPSS® (SPSS, version 11.0.1, 2002) for multidimensional scaling and cluster analysis, and Inspiration® (Inspiration, version, 6.0, 2002) for visual representation of data. This approach worked.

The study also identified some points for further consideration and improvement. The problem solving techniques supported knowledge elicitation in terms of comprehensiveness, but did not contribute enough to producing unconventional ideas. The method directed thinking toward what is in designing adaptive and active e-learning, but not enough toward what should be. This issue needs to be more explicitly addressed. One way to do it is to change the trigger statement format in the tradition of creative problem solving when applying techniques such as analogy level chain (Clegg & Birch, 1999), and personal analogy and wishful thinking (Michalko, 1998).

The method also claims to bring experts into agreement on the main characteristics of an adaptive e-learning environment. On the surface, this appears to be the case. However, despite a shortage of time, the method should involve experts more in the discussion of ideas generated after the brainstorming phase and interpretation of the results after sorting and rating.

The process of eliciting, sharing, representing, and creating ideas could be improved by using specific cognitive mapping software as Inspiration® (2002), Mind Manager® (2002), and Decision Explorer® (2003). They provide good opportunities for visual brainstorming, articulating, structuring, and analyzing ideas generated by a group of people.

Finally we cannot report on what the attitudes of experts toward the method were, or whether they were satisfied with the approach. Although our impression was that they were positive, it is a statement not based on a firm ground. The criterion of satisfaction should be included in further research. □

Slavi Stoyanov [slavi.stoyanov@ou.nl] and Paul Kirschner are with the Educational Technology Expertise Center, Open University of the Netherlands.

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Correspondence concerning this article should be addressed to Slavi Stoyanov, Open University of the Netherlands, Educational Technology Expertise Center, P.O. Box 2960, 6401 DL Heerlen, The Netherlands. Telephone: +31 (0)45 5762878. Fax: +31 (0)45 5762802.

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Appendix □ Rating of clusters and statements.

Statement	*Mean*
1. *Learner-led adaptation*	*3.810*
61. Learners should be able to select how they want to study (learning paths, scenarios, methods).	4.125
58. Learners should be able to receive instruction tailored to their abilities.	4.000
13. Learners should be able to select what they want to study.	4.000
74. Learners should be able to get content (tasks) that matches their existing knowledge and skills.	3.875
75. Learners should be able to find content (tasks) that fits their learning styles.	3.750
33. Learners should be able to select their preferred media.	3.125
2. *Learner-regulated studying*	*3.560*
34. Learners should be able to plan their study.	4.125
25. Learners should be able to select a learning task.	3.875
02. Learners should be able to define their own learning objectives.	3.750
71. Learners should be able to regulate their learning tempo.	3.750
51. Learners should be able to design their own learning experiences.	3.375
80. Learners should be able to get a customizable user interface.	2.500
3. *Learner self-management*	*3.870*
02. Learners should be able to search for content (learning tasks).	4.125
60. Learners should be able to monitor their learning.	4.125
78. Learners should be able to self-register for a particular course (UOL).	3.875
66. Learners should be able to see what are the next learning path, task and activity.	3.500
87. Learners should be able to consult course/ unit of learning (UOL) tracking data.	3.375
4. *Planning of learning*	*3.670*
76. Learners should be able to receive feedback from instructors.	4.250
53. A learning management system (LMS) should support learners to make good choices of what instruction to follow next.	3.500
55. Instructors should be able to facilitate (consult) learners to plan their learning.	3.250
5. *Learning auditing*	*3.750*
68. Learners should be able to see their learning results.	4.250
40. Learners should be able to test the level of their knowledge.	4.125
19. Learners should be able to test their learning styles.	2.875
6. *System administration and management*	*2.910*
86. Institutions should be able to certify level of achievements.	3.625
31. System administrators should be able to register learners.	3.500

Appendix ☐ (*Continued.*)

Statement	Mean
18. Instructors should be able to see learning tracks of learners.	*3.375*
42. System administrators should be able to provide quick and high quality help-desk.	3.000
59. System administrators should be able to provide statistics for learners' results.	2.875
65. System administrators should be able to keep track of student progress.	2.875
73. System administrators should be able to update learners' records.	2.875
12. Managers should be able to get an overview of the study progress of learners.	2.625
21. System administrators should be able to get information on drop-out rate.	2.250
85. System administrators should be able to prevent the overload of learners.	2.125
7. Technical standards	*3.770*
05. An LMS should be built with respect to security and privacy.	4.000
77. System administrators should be able to protect confidentiality.	4.000
17. An LMS should be compliant with technical standards.	3.875
67. An LMS should store learners' dossiers and portfolios.	3.875
84. Learners should have an alternative opportunity in case of (visual) handicapped.	3.500
88. An LMS should connect metadata to reusable learning objects.	3.375
8. Instructor support	4.050
37. Instructors should be able to create (design) new learning materials.	4.375
46. Instructors should be able to get support on developing instructional materials.	4.250
79. An LMS should allow variety of pedagogical models.	4.250
69. Instructors should be able to get an easy-to-use authoring tool for course designing.	4.125
32. Instructors should be able to construct a curriculum map for every single learner.	4.125
11. An LMS should support designers to design a good training.	4.000
16. Instructors should be able to select, adapt and rework content types from library of reusable learning objects.	3.750
30. Instructors should be able to construct their own learning environment, having components available.	3.500
9. Instructor-led adaptation	*3.430*
08. Instructors should be able to offer different didactic scenarios for different types of learners.	4.250
01. Instructors should be able to adapt learning content/tasks to existing knowledge and skills of learners.	4.125
07. Instructors should be able to adapt content (tasks) to learning styles of learners.	3.500
56. An LMS should dynamically adapt content (tasks) to learners' characteristics and performance.	3.000
06. Instructors regulate learning tempo.	2.125
10. Assessment	*3.660*
47. Instructors should be able to monitor and analyze the learning progress of students.	4.125
03. Instructors should be able to assess knowledge and skills of learners.	4.000
29. Instructors should be able to consult learners' portfolios.	3.875
27. Instructors should be able to build competencies' models of learners.	3.625
38. Instructors should be able to do skills gap analysis.	3.250
08. Learners should be able to "peer assess" other learners.	3.125
43. An LMS has an inbuilt assessment of whether the instruction is successful.	2.625
11. Instructor-regulated studying	*3.720*
09. Instructors should be able to provide feedback to learners.	4.250
44. Instructors should be able to provide guidance to learners.	3.750
04. Instructors should be able to determine the learning tasks.	3.500
23. Instructors should be able to facilitate (consult) learners to improve their learning.	3.375

Appendix ☐ (*Continued.*)

Statement	Mean
12. *Performance support for learners*	*3.780*
20. Learners should be able to get quick access to resources that support job performance.	4.375
52. Learners should be able to receive help just when they need it.	4.375
82. Learners should be able to get on-the-job performance support.	3.750
41. Instructors should serve as models.	2.625
13. *Administrative communication*	*2.880*
57. Instructors should be able to communicate with other instructors.	3.000
48. Instructors should be able to communicate with system administrators.	2.875
62. System administrators should be able to communicate with users.	2.750
14. *Collaboration*	*3.720*
49. Learners should be able to learn from peers.	4.125
24. Learners should be able to collaborate synchronously on learning task with other learners.	3.875
10. Instructors should be able to organize learners for group discussions.	3.750
63. Instructors should be able to structure group discussions.	3.750
15. Instructors should be able to organize both synchronous and asynchronous learning sessions.	3.750
50. Instructors should be able to moderate group discussions.	3.625
81. Instructors should be able to apply different modes of group discussions.	3.500
35. Instructors should be able to share synchronously applications with learners.	3.375
15. *Learning communication*	*3.920*
22. Learners should be able to communicate with other learners.	4.250
14. Learners should be able to communicate with instructors.	3.750
70. Instructors should be able to communicate with learners.	3.750
16. *Individual and group work*	*3.750*
64. Learners should be able to work on projects.	4.375
45. Learners should be able to study both individually and in groups.	4.000
83. Instructors should be able to work with an individual learner and with a group in a synchronous mode.	2.875
17. *Socialization*	*3.080*
28. Learners should be able to connect to experts' community of practices.	3.375
26. An LMS should provide social context.	3.000
54. Learners should be able to socialize with each other.	2.875