SUPPORTING A RANGE OF LEARNING STYLES USING A TAXONOMY-BASED DESIGN FRAMEWORK APPROACH

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Abstract

This paper describes the results of a UK research programme evaluating computer-based learning software and determining its suitability in supporting the different learning styles of users. A design taxonomy is proposed that helps designers build software to target multiple specific learning styles. This enables the courseware to be more user-friendly to a much wider audience, rather than just supporting one type of student. Then an example system is built using the taxonomy, supporting four teaching delivery approaches, and student and designers feedback is analysed to determine the accuracy of the taxonomy.

Keywords

computer-based learning, learning style, teaching delivery approach, simulation, taxonomy

Introduction

Computer-based learning environments are becoming increasingly popular in educational establishments and are based on a range of delivery and interactive services. These services may be composed of many different components, such as: video-conferencing, web-browsers, shared whiteboards, animations and simulations. However, for educational use, these technologies are not mere artefacts whose use is self-evident; they are open to interpretation which can influence both thinking and use (Schreiber & Berge, 1998). Therefore, it is not only important that students are given access to the most appropriate tools and environments that present information in an engaging manner, but that also provide appropriate support for the diversity of individual student learning styles.

Everyone has a learning style. Our style of learning, if accommodated can result in improved attitudes towards learning and an increase in productivity, academic achievement, and creativity. A learning style is a composite of characteristic cognitive, affective, and physiological factors that serve as a relatively stable indicator of how a learner perceives, interacts with, and responds to the learning environment (Messick, 1976). Learning styles also refer to the preferred way an individual processes information. Unlike individual differences in abilities, which describe peak performance, styles describe a person's typical mode of thinking, remembering or problem solving. Furthermore, styles are usually considered bipolar dimensions whereas abilities are unipolar (ranging from zero to a maximum value). Having more of an ability is usually considered beneficial while having a particular learning style simply denotes a tendency to behave in a certain manner. Learning style is usually described as a personality dimension, which influences attitudes, values and social interaction.

If deployment and the outcomes of using Computer-Based Courseware (CBC) are to be maximised then serious consideration must be given to developing applications that can support a range of learning styles. This paper will propose a framework that could help designers and courseware users consider teaching delivery mechanisms that can support such a range of learning styles during the design phase.

Learning Styles

Learning styles specifically deal with characteristic styles and models of learning. There are many definitions of learning styles and a number of these have been identified and studied over the years. Riding and Rayner (1998) identify four distinctly different types of learning style models.

The first ones are those style models based on the learning process and this approach was taken by Kolb (1984) and is referred to as Learning Style Inventory (LSI). Kolb (1984) proposes a theory of experiential learning that involves four principal stages: concrete experiences (CE), reflective observation (RO), abstract conceptualisation (AC), and active experimentation (AE). The CE/AC and AE/RO dimensions are polar opposites as far as learning styles are concerned and Kolb postulates four types of learners (divergers, assimilators, convergers, and accommodators) depending upon their position on these two dimensions. For example an accommodator prefers concrete experiences and active experimentation (CE, AE). There are limitations with this approach according to Riding and Rayner (1998) because it lacks psychometric rigour and empirical studies indicate a lack of verifiability using the measures in a pilot study. Riding and Rayner question whether the model is a description of a specific learning cycle rather than individual differences in the learner. This work was incorporated by Honey and Mumford (1986) in a Learning Styles Questionaire (LSQ) which received a mixed review from researchers indicating variable levels of psychometric rigour, especially in the area of predictive validity.

The second ones are those style models grounded in orientation to study and this approach was taken by several researchers including Entwistle (1981) and is referred to as Approaches to Study Inventory (ASI), also by Biggs (1978) where it is referred to as Study Process Questionnaire (SPQ) and by Schmeck (1988), referred to as Inventory of Learning Processes (ILP). ASI has good levels of empirical data; researchers reported a robust factor-structure with high levels of predictive validity. It provides a more useful tool for researching learning strategies. SPQ does not have as much empirical data to support it but it still provides a useful tool for researching learning strategies. Although there is not very much empirical data to support it ILP appears to carry good levels of reliability and validity; it also provides a useful reference for researching learning strategies.

The third ones are those style models based on instructional preference and this approach was taken by Price, Dunn & Dunn (1976, 1977) and is also referred to as Learning Style Inventory (LSI). The LSI in this context targets the learning environment although it has been criticised by some researchers for not providing data on differences within the learner.

The fourth ones are those style models based on cognitive skills development, this approach was discussed by Reinart (1976) and referred to as the Edmonds Learning Style Identification Exercise. (ELSIE). ELSIE is conceptually significant as a model as it is based upon the idea of field-dependence. Field independence versus field dependence is a learning style which refers to a tendency to approach the environment in an analytical, as opposed to global, fashion. Studies have identified a number of connections between this cognitive style and learning (Kolb, 1984). For example, field independent individuals are likely to learn more effectively under conditions of intrinsic motivation (e.g. self-study) and are less influenced by social reinforcement.

Pask (1975) has described a learning style called serialist versus holist. Serialists prefer to learn in a sequential fashion, whereas holists prefer to learn in a hierarchical, top-down manner.

Howard, Carver & Lane (1996) highlight the benefits from using a range of learning styles when teaching computing students. Such techniques if they were to be incorporated into CBC applications would improve learning outcomes for many students. In a recent research study

(Carswell, Thomas, Petre, Price & Richards, 2000) the authors identify the impact of learning styles using Internet-based teaching mechanisms and claim that the support of a range of learning styles is important in delivering good learning outcomes.

The authors recognise that there are many definitions of learning style in use and have specifically chosen to support a model based on instructional preference for the purposes of this research. It is considered that an instructional preference approach to CBC design offers the user the greatest clarity in making the appropriate choice for their preferred learning style. This decision also places the control of learning approach in the users' hands.

Supporting Learning Styles in Design

Theoretically, learning styles could be used to predict what kind of instructional strategies or methods would be most effective for a given individual and learning task. It is said that optimal learning results when the instruction is exactly matched to the aptitudes of the learner (Cronbach & Snow, 1977).

The requirement to provide a range of teaching approaches was highlighted by Jones (Jones, Jacobs & Brown, 1997) in response to UK Government reports on the impact of technology on teaching and learning (Dearing et al., 1997). Jones et al., (1997) state: 'Clearly developing a single piece of courseware which simultaneously provides guided sequential learning for one set of students and discovery-based exploration and browsing for another, together with a range of hybrid options for those learners who may prefer a mixture of the two, is a demanding task, though not an impossible one for the future, and even, given the flexibility of current technology, to some extent for the present.'

In a research report (Bates, 1998), the author describes in detail the characterisation method and taxonomic framework in building a real example: a series of control laboratory experiment applications. In this example, four different teaching delivery approaches were chosen and characterised using five primary classification issues. These were:

- Drill experiment;
- Tutorial experiment;
- Simulation experiment; and
- Modelling experiment.

By considering these four teaching delivery approaches, a diagram was constructed to show how the level of interactivity varies according to the level of student control, see Figure 1. This shows that the four teaching delivery approaches include guided sequential and discovery-based student exploration as required above.

<table>
<tr><td>High
Interaction</td><td colspan="2"></td><td colspan="2">Modelling Simulation
(Discovery Learning)</td></tr>
<tr><td>Some
Interaction</td><td></td><td colspan="2">Tutorial
(Guided Sequential Learning)</td><td>Interactive Simulation
(Guided Discovery Learning)</td></tr>
<tr><td>Low
Interaction</td><td colspan="2">Drill
(Sequential Learning)</td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2">Teacher Controlled</td><td colspan="2">Student Controlled</td></tr>
</table>

Figure 1: How each teaching delivery approach affects interaction

Design Approach Framework

The emergence of desktop multimedia personal computers and the general availability of multimedia authoring packages have enabled educationalists and commercial organisations to produce more CBC. Even before this recent change in general availability of technology, researchers such as Bialo and Erickson (1985) were highlighting problems in CBC. Their research covering 163 applications identified basic problems such as clarity of learning objectives, appropriate goals and content, appropriateness of software for particular users and a general lack of supporting materials. Harrison (1994) states that learning technology should be more concerned with the design of the whole learning experience rather than an emphasis on a particular learning delivery medium.

In a research report the author (Bates, 1998), described a taxonomic design approach to developing computer simulated experiments which included a series of trials of a software demonstrator designed using the taxonomy as an explicit design guide. The research identified five primary characterisation issues, which can determine the profile of a teaching delivery mechanism. These were goals, guidance, interaction, instructional process and modelling complexity.

Goals are concerned with identifying what level of goal setting is possible and whether the user has any freedom in setting the learning goals for a particular application. The characterisation process seeks to determine if goals relate to individual tasks, complete topics, overall learning objectives or can they be determined by the user.

Guidance is concerned with specifying what level of application support the user receives when interacting with an application. Such support can range from simple confirmation of right/wrong answers to questions, prompting to give clues when wrong answers are given, through to complex responses to changes of user variables in the user interface.

Interaction seeks to determine what level of interactivity is possible with the user interface. This ranges from yes/no questions, to experimenting with values, multiple variable assignment, through to users supplying their own simulation model.

Instructional process ranges from a user solving an individually distinct problem, identifying concepts or rules, discovering a best strategy to solve a problem, discovering optimal values for several variables, through to applying knowledge acquired in a particular area through the use of an evaluation or modelling technique.

Modelling complexity characterises the type of model the user will interact with directly or indirectly when using the software. This affects such things as the number of variables changeable at the user interface through to the complex interaction with the system with users' own models.

These five primary characterisation issues were then used to characterise the four different teaching delivery approaches described earlier. Table 1 shows the characterisation categories.

	Primary Characteristic Issues (determine teaching delivery approach)			
Characteristic Category	**Lowest Complexity**	**Low Complexity**	**High Complexity**	**Highest Complexity**
Goals	Task	Topical	Overall	Definable
Guidance	RightWrong	Prompting	Outcomes	Directive
Interaction	Simple	Experimental	Multivariable	Engaging
Instructional	Discrete	Conceptual	Strategy	Embracing
Modelling	None	Singular	Multiple	Complex

Table 1: Categories and levels of characterisation issues

Each characteristic issue is divided into sub-characteristics. It is the presence or absence of these sub-characteristics, which uniquely define a particular environment; be it Drill, Tutorial, Simulation or Modelling. The detail of each of these can be seen in Table 2 which shows a summary of which primary characteristics were embedded in which particular teaching delivery approach. The profile of primary issues has been set to characterise the four teaching approaches chosen: Drill, Tutorial, Simulation, and Modelling.

	TEACHING DELIVERY APPROACH				
Category	**Sub-Category**	**Drill Experiment**	**Tutorial Experiment**	**Interactive Simulation Experiment**	**Modelling Simulation Experiment**
Goals	Definable			YES	YES
	Overall			YES	YES
	Topical		YES		
	Task	YES			
Guidance	RightWrong	YES	optional	optional	optional
	Prompting		YES	optional	optional
	Outcomes			YES	optional
	Directive				YES
Interaction	Simple	YES	optional	optional	optional
	Experimental		YES	optional	optional
	Multivariable			YES	optional
	Engaging				YES
Instruction	Discrete	YES	YES	optional	optional
	Conceptual	YES	YES	YES	YES
	Strategy	YES		YES	YES
	Optimal			YES	YES
	Embracing				YES
Modelling	None	YES	YES		
	Singular	YES	YES		
	Multiple			YES	YES
	Complex				YES

Table 2: Taxonomy characterisations for primary design issues

Description of Software Package

The software was developed using a commercially available software tool (Asymetrix, 1994). The system was divided into four major sections: Tutorial, Drill, Simulation and Modelling. Two underlying analogies were used to provide a background for students to study. The first was the analogy of a water tank with a leakage factor proportional to the height of water in the tank. The control goal was to maintain the height of water in the tank by controlling the inflow of water. In the second case the analogy was of a room, heated by an energy source, which loses heat proportional to the difference between the room and the outside temperature. The control goal in this case was to maintain the inside temperature of the room by controlling the flow of energy into the heater.

The flow of this approach can be seen in Figure 2. The main menu, see Figure 3, enables users to select the control analogy and the learning environment required (e.g. Drill etc.). Upon selection of the appropriate button the user will then enter one of the four learning environments.

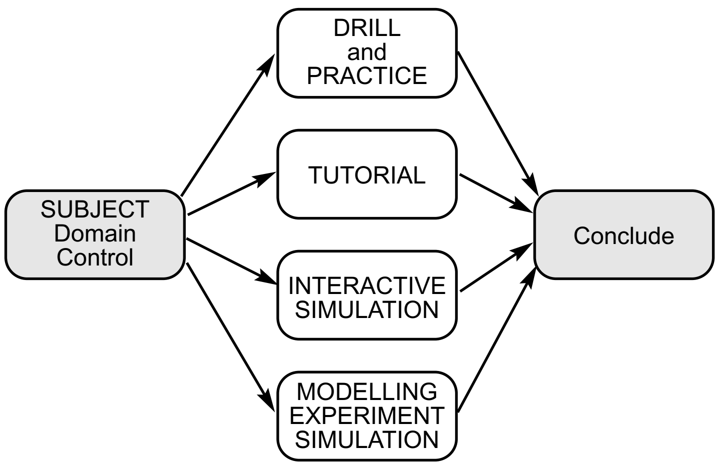

Figure 2: Choosing teaching approach path

The Tutorial environment contains four major sections; Principles of Control, Designing Control Systems, Systems to be Controlled and Methods or Modes for Control of Closed Loop Control Systems. These sections all have a series of information screens with an access button to Self Assessed Questions (SAQ) to test the user's knowledge of the subject material they have covered in the current section.

The Drill and Practice environment contains five pages of different yes/no answer drills. The idea is to test the user's knowledge of the subject by only asking single answer questions. The Simulation environment is the first occasion where the user will meet a simulation process explicitly, although the simulation engine is embedded in every environment of the software. Figure 4 shows a typical open loop simulation run. Users can vary parameters and perform user defined simulation runs. The Cfg button allows users to change the control algorithm used as well as change the outside temperature for the heated room analogy. Users can print a hard copy of any of the graphs plotted by the simulator.

The Modelling environment allows users to perform simulations and transfer the run-time parameters to a Dynamic Data Exchange (DDE) linked spreadsheet and compare their own developed model with the one embedded in the Control Laboratory software. This particular environment is the most sophisticated learning environment supported by the system. The results are imported from the spreadsheet and plotted on a composite graph.

Figure 3: Control laboratory 'main menu'

Results and Evaluation

Field trials of the software demonstrator were conducted using a user questionnaire incorporating the taxonomy characterisation described in Table 2. The sample population used consisted of a group of 30 students and lecturers. The researchers analysed the results to answer three fundamental research questions:

how consistent is the taxonomy perceived by a range of users;
can the taxonomy differentiate across the four different teaching approaches selected; and
how visible are the designer's intention to users.

The purpose of doing such a questionnaire survey was to check the visibility of the different characteristic issues to users and to evaluate the consistency of results over a sample population against the original design intentions.

The survey and full results are detailed in Bates (1998). The results of the survey were analysed using three different statistical analysis methods. The first method was the *t-test*, which was used to test for consistency over a range of users. The second method was a one-way ANOVA, which was used to check that the different teaching approaches (Drill, Tutorial, Simulation, and Modelling) were significantly different from each other. The third method was a simple comparison of statistical mode, between the designer's intention and the users' perceptions.

The characteristic category Goals proved not to be consistent and more work needs to be done to develop Goals by reviewing the characterisation criteria and extending the demonstration software to incorporate a wider range of characterisations. Guidance revealed some misunderstanding between Drill and Tutorial as students found it difficult to differentiate these two approaches. Tutorial approach differs from the Drill approach in as much that feedback it provides to users is more helpful and informative. In general, with the exception of the above limitations, the quantitative research activity confirmed that the proposed characterisation process and taxonomy was consistent to a wide range of users, accurate in differentiating between applications approaches and users were able to identify, in most cases, the original designer's intentions.

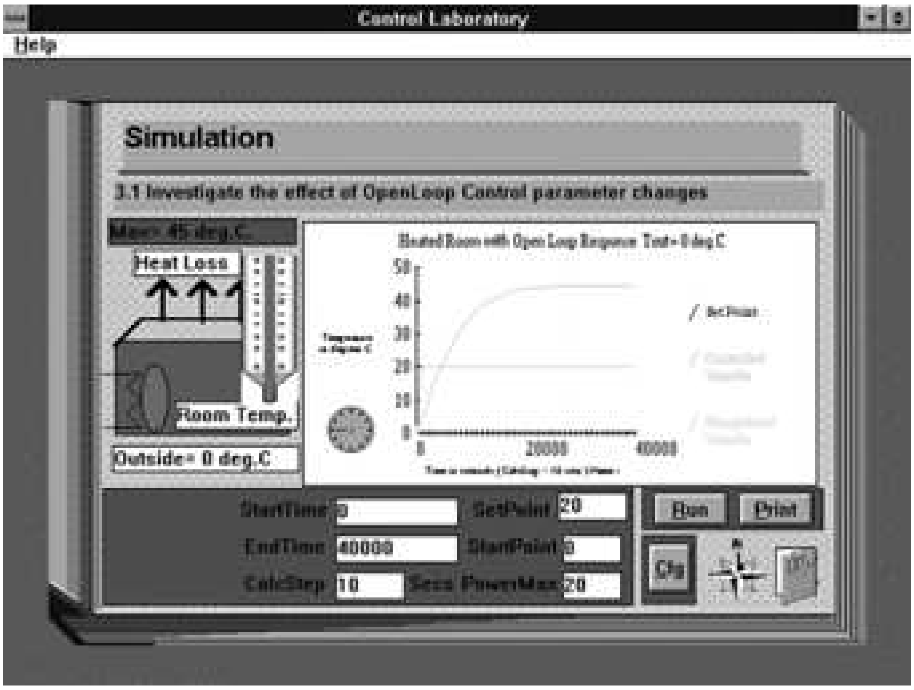

Figure 4: Control laboratory 'simulation menu'

The experience from designing the demonstrator led the researchers to construct a flow diagram to illustrate how the taxonomy can be applied to designing educational software, see Figure 5. Four out of the six stages of the proposed design process involved using the taxonomy directly. These were: Specification (identifying learning approaches required), Interaction (deciding on appropriate user interaction strategies), Analysis (analysing the design from a developer's perspective) and Evaluation (evaluating the user perceptions).

Conclusions and Future Work

This paper has highlighted the need to develop software for CBC environments that is capable of supporting a range of student learning styles. It has shown that there are some distinct advantages in using a taxonomic driven design and evaluation approach, which gives clear guidance to designers wanting to develop software to support a range of learning approaches. However there are a number of limitations in the taxonomy characterisation presented, which need to be addressed in future research work. The characteristic Goals was the most difficult to categorise. The quantitative research analysis revealed problems when evaluating the software demonstrator. This would indicate that these issues need to be more carefully embedded into an application. This work did not address the area of collaborative or co-operative issues, which are becoming increasingly important especially in a distance-learning context. The software demonstrator developed was for a specific subject domain (control engineering) and whilst this was quite mathematically demanding it would be useful to develop further demonstrators to see if this approach could be applied in other more generic teaching and learning contexts.

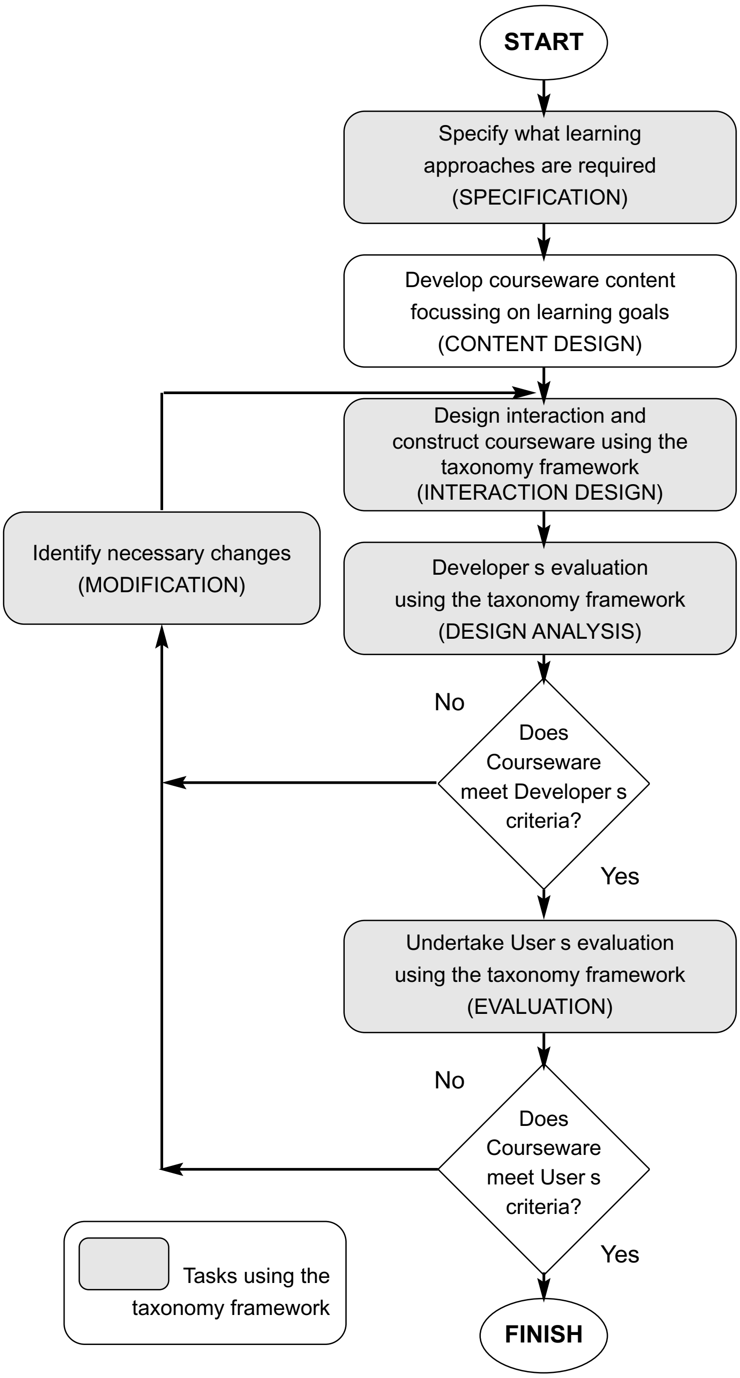

Figure 5: Flow and use of the taxonomy

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