Managing the Interactivity of Instructional Format and Cognitive Style Construct in Web-Mediated Learning Environments

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Abstract. The management of Web-mediated learning environments is complex. There are many ontological facets to account for in defining the interacting variables. Instructional designers need to be ready to correctly identify and unravel each variable [1]. A meta-knowledge processing model has been proposed to facilitate the courseware design process to enhance performance outcomes [2]. Research has already been carried out on each component, however very little is known about the interactivity of these components in a Web-mediated learning environment. While multi-sensory instruction is known to improve a student's capacity to learn effectively, the overarching role of knowledge-mediated human-computer interaction (HCI) has been poorly understood [3]. The purpose of this paper is to discuss this meta-knowledge processing model and its usefulness for Web-mediated learning platform design in general and in particular to identify the interactive effects of the cognitive style construct and instructional format on performance outcomes.

1 Introduction

The purpose of this paper is to promote the use of the meta-knowledge processing model (see Figure 3) to aid in the process of effective courseware design that initiate instructional outcomes that are predictable. The interactive effect of differences in cognitive style construct (*how we represent information during thinking and the mode of processing that information*) [4] and instructional format (*verbal(text)/image(pictures)*, have shown surprising results when applied to instructional materials that are solely paper based [5]. There is no research that can inform what happens with this interactive effect of individual differences in cognitive processing in a Web-mediated context. To compound the complexity of providing interactive courseware, there are additional challenges ahead for researchers to investigate how the effects of audio, colour and movement affect the learning performance outcomes. This paper provides a brief overview of the contextual issues involved in understanding the interactivity of Web-initiated instructional conditions and the cognitive style construct as a meta-knowledge acquisition process. This mechanism may explain how

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individuals deal with the Web-mediated instructional format in terms of information processing, in the form of a speculated internal/external exchange process [6]. The discussion leads to a final conclusion, that reflects on how much work is ahead to uncover the best eLearning design and development specifications.

Web-mediated communications technologies seem to offer new instructional/learning opportunities. However, this view takes a pervasive approach to the individualised instructional requirements of diverse cohorts in Web-mediated learning programmes. Current thought on the multimedia technologies engaged in eLearning courseware development accentuates a presumed requirement for highly graphical (or visual) approaches to instructional formats. Unfortunately, providing textual displays will also encounter difficulties for the courseware designer. When the format involves screen-based textual displays, there are extra mitigating factors that involve an interaction between the learner managing the scrolling text and dealing with the comprehension of large amounts of information. While the so-called eLearning programmes may appear to enable a learner to proceed at their own pace [7], there is a common assumption made by instructional designers, that to facilitate eLearning, all learners are capable of assimilating the graphical material with their current experiential knowledge. There is little or no consideration for differences in cognitive styles!

Due to the far reaching effects of Web-mediated instructional systems (WMIS) in terms of development costs, let alone the HCI factors, there is often a need to accommodate co-existing instructional paradigms in any computerized learning/course authoring process. This inevitably requires a dynamic evaluation of task knowledge level requirements that responds appropriately to individual cognitive styles and the learner's knowledge acquisition requirements. Meta-knowledge acquisition strategies are thus essential to provide the mechanisms for the dynamic knowledge analysis necessary for knowledge-mediated instructional processes within Web-mediated learning environments. The complexity of the visual learning environment has been identified [8]. Prospects for an interactive customised learning shell, based on meta-knowledge have also been researched [2]. Unfortunately due to the abundance of technological choice, practitioners have been slow to implement educational research findings; however, progress can now be made in linking research outcomes to actual learning environments. The prospect of customised eLearning courseware, dynamically tailored to the requirements of individual students, has stimulated contemporary research into knowledge mediation. Consequently, the associated meta-knowledge acquisition strategies of learning contexts within Web-mediated instructional programmes can now be designed as synchronous and asynchronous learning frameworks.

Within the context of online asynchronous learning platforms, there is a noticeable shift from traditional teaching methods, which act as the sole content provider, towards a multiple mentor-guiding approach. This approach supports learners through the process of knowledge acquisition, but relies largely on the learners to direct the learning process themselves; reflecting a lack of understanding of the effect of computerized learning on the population at large. HCI is complicated, and Web-mediated courseware designers should ensure that careful attention is paid to sound and well-founded instructional design principles. In general terms, online courseware designers will need to be aware of the meta-knowledge acquisition process, relevant instructional strategies, and need to articulate the *conditions-of-the-learner*; specifically, drawing on comprehensive Web-based ontological models to direct the online learning experience that best achieves high quality instructional outcomes. It should be noted that understanding the *hierarchical structuring of knowledge* (ontological complexity) will be necessary to bring about the types of learning models that institutions and private consortia require [9].

This paper therefore presents a paradigmatic approach towards a knowledge-mediated learning environment. Aspects of instructional science, cognitive psychology and educational research are combined to articulate the ontological requirements of Web-mediated learning courseware. The discussion will firstly identify the cognitive style construct as an effective means to explain how human beings process information they receive. Next will be an outline of the research that has shown there are certain cognitive style dimensions that enable knowledge acquisition more readily than others. Then, an information processing framework is proposed to support the complexities of Web-mediated instructional environments. There is an explanation that spatial ability and notational transfer, involving the relationship of instructional format and the cognitive style construct may interact with particular tasks during the knowledge acquisition of abstract concepts. The WMISs' multimodal capacity is included to introduce the notion of cultural specificity as another important area for future research.

2 Cognitive Style Construct

The literature reveals research which distinguishes human ability to process information, as a combination of *mode of processing information*, and the *way people represent information during thinking* [10]. Moreover, there are two fundamental cognitive dimensions: Wholist-Analytic and Verbal-Imagery that affects performance in two ways. The first way, is in the way we perceive and interpret information we are given. While the second way is how we conceptualise related information already in our memory [11].

Cognitive style is understood to be an individual's preferred and habitual approach to organizing and representing information. Measurement of an individual's relative right/left hemisphere performance and their cognitive style dominance has been a target of researchers from several disciplines over the last decade. Different theorists make their own distinctions on an individual's cognitive differences [4]. The naming of their Wholist-Analytic (WA) continuum for example, maps to the cognitive categories used by other researchers. These well known terms are used frequently throughout the literature in a number of different research disciplines.

2.1 Wholistic/Analytic (Mode of Processing Information)

The Wholist-Analytic dimension defines that Wholist learners are able to perceive the whole concept, but may find difficulty in disembedding its separate facts [12]. Analytic learners analyse material into its parts but find difficulty in seeing the whole concept.

2.2 Verbal/Imagery (Mode of Representing Information while Thinking)

The Verbal-Imagery continuum measures whether an individual is inclined to represent information verbally, or in mental pictures, during thinking [13]. Verbalisers prefer and perform best on verbal tasks; while Imagers are superior on concrete, descriptive and imaginal ones [14]. When there is a mismatch between cognitive style and instructional material or mode of presentation, Riding argues that performance is deemed to be reduced. The suggestion is made here that as not everyone can see the same graphical detail presented in traditional materials, and therefore Web-mediated courseware design may also prove to be even more complicated. For instance, the well known graphical representation below that was first published in 1915 as a puzzle type picture to depict a multiple depiction of *a wife and a mother-in-law.* Without any prompting, some will see the profile of a young woman, while others will notice an old lady's face instead.

Fig. 1. Different Ways of Seeing [15, 16]

2.3 Complementary Style Dimensions

The full effects from the interaction of the cognitive style construct and instructional medium on learning in WMIS is unknown. There are few published studies which deal with the interactive effects of the cognitive style construct and multimedia delivery techniques, on performance outcomes [17]. However, courseware designers are well advised to examine the valuable contribution that has been made to enable comprehension of the differences in learning and behaviour as a complex human interaction [13]:1: "*The concept of style is an idea used frequently in everyday language. The concept has been used more technically in the psychological study of individual differences in learning and behaviour. In this respect it is used as a 'construct'. A construct is a psychological idea or notion....*"

According to Riding, the Wholist-Verbalisers are likely to utilize their dominant style for verbal representation of information, having the characteristic of both semantic coding and a degree of analytic facility as well as having an ability to internally process what they see as imagery, which has both a pictorial quality and its associated wholeness. On the other hand, the Analytic-Verbalizer and Wholist-Imager combinations, are both less complementary, with the former having difficulty visualizing how facts and details fit into the bigger picture, and the latter unable to focus on detailed information [18]:210.

An investigation of the effects of instructional format (*textual metaphors* (T:1) or *graphical metaphors* (T:2)) on the performance of learning computer programming concepts (see Figure 2) has defied common assumptions about the effects of cognitive style and instructional outcome [5]. It shows that researchers should examine the interactive effects of the integrated cognitive style (ICS) construct sub-groupings (Wholist-Verbaliser, Analytic-Verbal, Wholist-Imager, Analytic-Imager) and instructional format on actual performance outcomes. Although the initial data analysis indicated that Wholists out-performed Analysts (dimension for mode of processing information), and Verbalisers out-performed Imagers (dimension of representation of information during thinking); closer examination of the full cognitive dimensions reveals that actually the Wholist-Verbalisers using the graphical treatment (T:2) were only 3rd in the performance level sub-grouping, with the Wholist-Imagers:T:2 and Analytic-Verbalisers:T2, being the top 2 sub-groups [5].

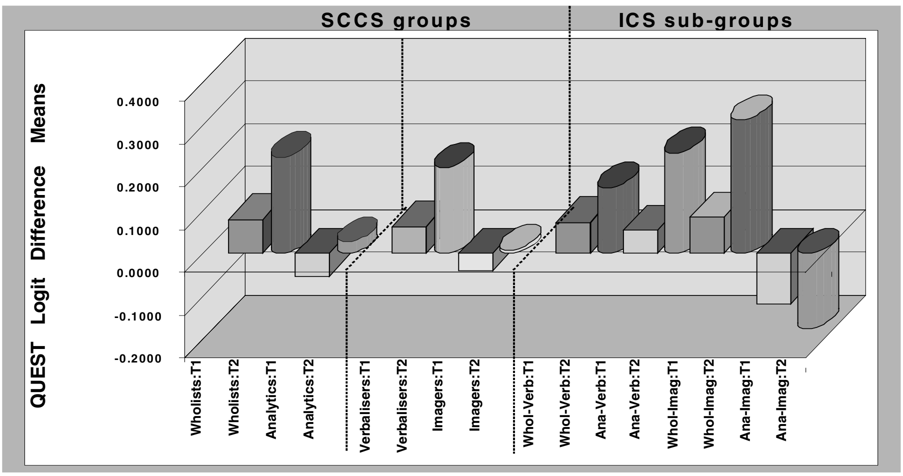

Fig. 2. Experimental Results

Conversely, given the relatively poor performance of the Analytic and Imager single category cognitive style (SCCS) groups (Wholist/Analytic, Verbaliser/Imager), it is not surprising that the Analytic-Imager ICS sub-groups performed badly. It is surprising that the results indicate that an Analytic-Imager would perform best with the textual treatment (T1). There are two interesting factors for the acquisition of programming concepts, which emerge from these findings. Firstly, is the suggestion, that in devising a prescriptive model for expressing concepts of computer programming in terms of content specific knowledge elements, there is a need to provide a notational representation of the instructional strategy with a mix of text and graphical metaphors. This instructional format will benefit most learners, including Verbalisers. Secondly, and the most striking, is that some learners (Analytic-Imagers) will perform better with a text-only instructional format.

3 Information Processing Framework for HCI

The means to provide Web-navigation exists, even at the most basic level, with well planned hyperlinks and floating menus. Yet novice-learners are often left to navigate Web-mediated courseware alone. Generic instructions will not provide sufficient information to reach a diverse mix of global learners in a WMIS. In a traditional learning setting there are three major components of a theory of instruction: methods, conditions, and outcomes [19]. Courseware designers need to be aware of these components to understand how best to articulate these components into a WMIS.

Methods are the different ways to achieve different learning outcomes under different conditions. For instance: methods can take the form of an instructional agent (maybe a teacher, or some other instructional medium), that directs its actions at a learner [20]. This context-mediated modeling tool could include an instructional conditions agent in an online context. *Conditions* are the factors that influence the effects of the instructional methods employed. Instructional conditions have a two-fold impact [19]. Firstly, courseware designers may be able to manipulate them as some conditions interact with the method of delivery to influence their relative effectiveness, such as instructional format. Secondly, there are instructional conditions that cannot be manipulated, and, therefore, are beyond the control of the designer, such as learner characteristics. This is the most complicated component in a WMIS. *Outcomes* are the various effects that provide a measure of value of alternative methods under different conditions, as they focus on instruction rather than on the learner [19]. Assessment practices in diverse cultures and learning domains will be studied using the model depicted in Figure 3. Note that the term conditions-of-the-learner [19] combines the interactive effects of the internal states of an individual and external events of the instructional delivery format on learning [2]; providing in eLearning environments the computer-mediated context. More work is needed to clarify how people respond the Web-based education.

The Meta-Knowledge Processing Model (Figure 3) articulates the complexity of the eLearning delivery environment [21]. The *Method of Delivery Transfer Agent* directs the *Instructional Conditions* according to the results of the *Learner Characteristics* (cognitive style) and *Event Conditions* (complexity of processing the learning material), and the *Measurable Instructional Outcomes*. Directions for choice of *Instructional Format* are given by the *Method of Delivery Transfer Agent* (or learner). Therefore it is useful to draw on this model as a courseware design tool to identify and thoroughly examine the characteristics of each component. For example, consider how the *method of delivery* (a palm pilot) would need to reflect the interactive effect of the expected learner profile *learner characteristics (*when the learners use English as a second language) and *instructional format* (the provision of sufficient conceptual translation opportunities to achieve the *measurable instructional outcomes*).

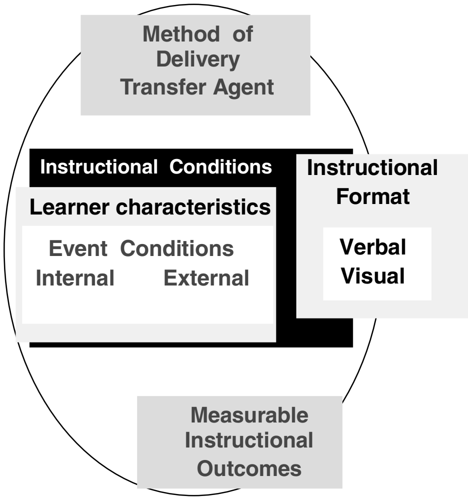

Fig. 3. Meta-Knowledge Processing Model

WMISs involve a complex pedagogical process that courseware designers struggle with. In the first instance, there should be an understanding of how the learners will deal with the instructional content. Next, is the recognition of the interactive effect of an individual's knowledge processing and the dimensions of their cognitive style construct. Finally, is the need for an awareness of how the dynamics of the Meta-Knowledge Processing Model will impact on the media engaged to bring about the instructional outcomes.

In most instructional programmes, it is not sufficient to say that one size fits all. The same can be said about the likely success of a WMIS. More work is needed by researchers to determine how dissimilar cognitive styles react, resulting in superior performance outcomes by learners with one cognitive style drawing on a particular condition of an eLearning instructional strategy, as opposed to another [21].

An explanation for how the Riding and Rayner [13] cognitive style construct interacts with a particular abstract or conceptual task that involves procedural programming knowledge may lie within the relationship of the instructional conditions' components as shown in Figure 3. It should be no surprise that individuals' performances vary on the strength of their cognitive style, and the task at hand. Because there is an interactive effect of graphical instructional metaphors on logical reasoning and spatial relations, a number of questions arise: can an explanation for this be found using between-item and within-item elaborations. Furthermore, can visual metaphors, used as internal/external exchange agents [6], have the same interactive effect (for some novice learners) in environments other than the computer programming domain? How will a WMIS impact on an individual's capacity to learn?

4 Spatial Ability and Notational Transfer

In the past, verbal (or analytic) ability was taken to be a measure of crystallised intelligence, or the ability to apply cognitive strategies to new problems and manage a large volume of information in working memory [22], while the non-verbal (or imagery) ability was expressed as fluid intelligence [23]. However, as electronic courseware lends itself to integrating verbal (textual) with non-verbal (graphical representations) and sound, instructional conditions that generate novel (or fluid) intellectual problems. Research into the effects of Web-based educational systems on knowledge acquisition must be carried out to provide instructional designers with prescriptive models that predict measurable instructional outcomes for a broader range of cognitive abilities. To this end an empirical experimental research methodology for cognitive performance measurement in a WMIS should be undertaken to facilitate the prediction of whether: the method of delivery affects highly-verbal/low-spatial learners, because they need a direct notational transfer agent [6]; or whether the instructional conditions disadvantage high-spatial/low-verbal learners, because they will be less able to pick out the unstated assumptions [6].

Picking out these important instructional variables for some types of instructional outcomes provides appropriate instructional environments for a broader range of novice-learners by means of an information-transfer-agent, thereby controlling the choice of instructional format and instructional event conditions. Isolating the key components of the instructional conditions provides the means to manipulate the method-of-delivery, which in turn may bring about a choice of information-transfer-agent (see Figure 4).

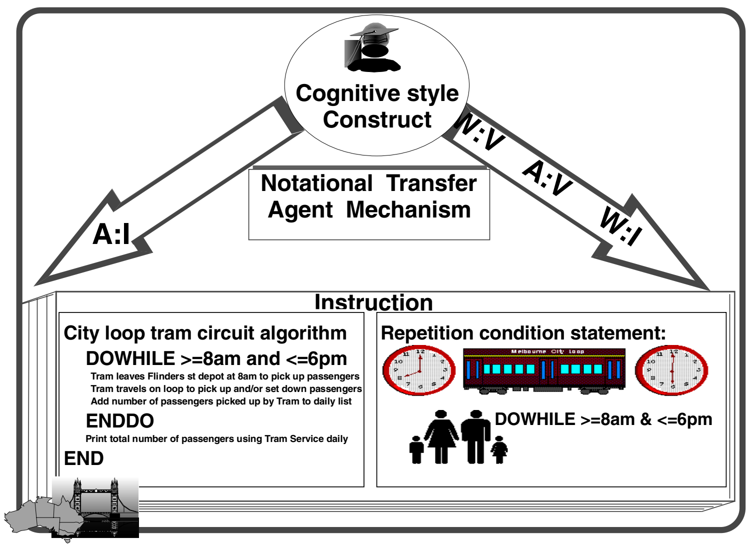

Fig. 4. Notational Transfer Agent

It is proposed that the external-representation of the instructional material may require a direct notational transfer of the symbol-system used for the instructional strategy (from the external representation of the instructional material to an internalised form in an individual's memory) [24]. For instance: the graphical details in a road map directly relate to the physical environment (in a 1:1 direct notation ratio, like the explicit representation of basic data-type rules in computer programming). Therefore, in a programming environment, another example would be that a real number must not contain a decimal point [6]. On the other hand, the embedded details in an abstract metaphor are said to require a non-notational transfer process. For instance, the programming loop shown as a graphical metaphor in Figure 4 requires a 2:1 transfer for the non-notational characteristics of the external representation to a single internal notational representation [6].

Taking this type of fine grained approach to locating the complexity of the ontological requirements will provide Web-designers with special insight. Courseware authoring that offers a WMIS without involving a customizable platform to individualize instructional strategies is much like implementing the closed systems of days gone by, and given the passing of time, this type of closed WMIS will inevitably fail [25].

5 WMIS and Cognitive Context

Multi-sensory instruction that involves choice of Web-mediated instructional media is emerging through the literature. Web technology has brought with it a resurgence of interest in knowledge acquisition through HCI. This important work began over four decades ago with the George Pask's famous conversation theory [26, 27]. Since then researchers have been wishing to develop learning systems that better resemble human beings. These attempts have been to have a computer mimic how humans think by establishing problem spaces, where there are a number of dimensions to deal with communication channels in a technical sense, while others characterise the complex nature of the system's cognitive ability [28]; [29]. While others concentrate on finding ways to develop interface technologies which posses multimodal capabilities to offer speech, and body language that includes: gestures, eye-gazing, lip motion and facial expressions [30].

Yet another Web-mediated instructional paradigm which is now popular are the instructional agent technologies. This research group is concentrating on bringing interactive interfaces which behave like human beings. However, in dealing with the technology aspects of HCI some of the importance of providing interactive learning systems which respond according to learner differences is lost. One such attempt to provide an intelligent tutoring tool which took a multi-sensory approach to the instructional strategies was a computer-based training (CBT) package called Cogniware launched in Taiwan (see Figure 5). Cogniware offers a range of instructional format (text, voice, and video) [31].

To exploit an individual's cognitive learning characteristics, Cogniware consists of a front end module that determines the learner's cognitive style, and offers a choice of instructional formats for the acquisition of programming concepts. Learners are encouraged to investigate the alternative instructional strategies. Cogniware is multi-sensory in the sense that the instructional strategies on offer provide the learning content in a range of alternative instructional modes. Figure 5 depicts a typical Cogniware interface with three instructional formats or separate viewing areas: graphical, textual, and voice. There are also cueing mechanisms for guided exploration, such as: directional icons, a learning module name tag, and an advance organizer screen.

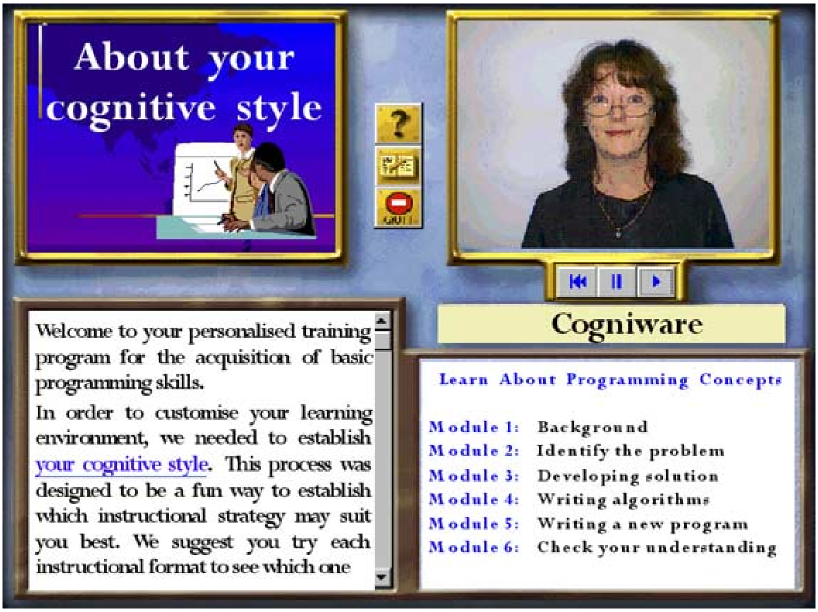

Fig. 5. Multiple Instructional Format

Research into the anthropocentric aspects of WMISs is scarce. However, it would appear there are many technological mechanisms to support the Web-mediated learning process per se; and certainly, the advent of the Web has far reaching effects for global connectivity.

6 Summary

This paper provided an overview of the contextual issues which surround the design of a WMIS. Management of the interactivity of the various aspects of multimedia and individual differences in a Web-mediated learning programme were explained. The meta-knowledge processing model was suggested to articulate the complex ontological requirements which involve aspects of instructional science, cognitive psychology and educational research. It has been suggested that rather than isolating the two dimensions of cognitive style (Verbal-Imagery (V:I), Wholist-Analytic (W:A)) to identify the representation of information during thinking (V:I), and the mode of processing information (W:A) as described by Riding and Cheema [4], courseware designers need to give consideration for the complete dimensions of the cognitive style construct that affect performance the most in respect to instructional media. Notational transfer, a phenomenon which occurs within a learner during a learning experience has been referred to in this paper as an internal/external exchange process [2]. More research should be done before we can be certain about the effectiveness of Web-mediated instructional systems, especially in multi-cultural settings.

It is expected that this research perspective generates considerable interest in the important relationships between cognitive psychology, educational research and instructional science, which have not previously been elaborated in a unifying context or meta-knowledge framework. HCI by its very nature brings together a number of professional practices. HCI comprises elements of computer science, cognitive psychology, social and organization psychology, ergonomics, human factors, artificial intelligence, linguistics, philosophy, sociology, anthropology, engineering and design [25]. Consequently there are many ways in which instructional designers will approach their work. However, it can only be through the synthesis of the shared knowledge gained from these different perspectives that true progress will be made towards efficient and effectively managed interactive online instructional environments.

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