An Exploratory Study of the Relationship between Learning Styles and Cognitive Traits*

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Abstract. To provide personalization and adaptivity in technology enhanced learning systems, the needs of learners have to be known by the system first. Detecting these needs is a challenging task and therefore, mechanisms that support this task are beneficial. This paper discusses the relationship between learning styles, in particular the Felder-Silverman learning style model, and working memory capacity, a cognitive trait. Due to this relationship, additional information about the learner is available and can be used to improve the student model. An exploratory study is presented to verify the identified relationship based on the literature. The results of the study show that the identified relationship between working memory capacity and two of the four dimensions of the learning style model is significantly supported. For the two remaining dimensions further research is required.

1 Introduction

Modelling the characteristics of learners is important for all systems that incorporate personalization issues and especially for systems that aim to provide adaptivity. Student models (for example, see [2]) are crucial components of technology enhanced educational systems dealing with personalized learning. They store information about learners such as personal data, domain competence, learning styles, and cognitive traits. To adapt to the learners' needs automatically, this information needs to be known by the system first. One challenge of student modelling is to identify the needs of the learners. The simplest approach to inform a student model is to ask the student for the required data. However, this approach is not suitable for getting accurate

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information for several components of a student model, such as cognitive traits, domain competence, and learning styles. For example, the estimation of domain competence is subjective and for identifying the cognitive traits and learning styles, comprehensive tests or questionnaire-based surveys have to be performed. An alternative approach is to track the students' behaviour and infer the required information from this behaviour. The challenge of this approach is to identify enough information from the learners' behaviour.

To support the information detection process, it is beneficial to find mechanisms that use whatever information about the learner is already available to get as much reliable information to build a more robust student model. In this paper we investigate the relationship between learning styles, in particular the Felder-Silverman learning style model (FSLSM) [5], and working memory capacity, which is one of the cognitive traits included in the Cognitive Trait Model (CTM) [8]. This relationship provides additional information which can be used to improve the identification process of both, the learning style and the cognitive traits, in an adaptive virtual learning environment.

In the next section background information about FSLSM and CTM is provided. Based on the identified relationship from the literature, we present in Section 3 an exploratory study to verify this relationship. Section 4 concludes the paper.

2 Background

In this section Felder-Silverman learning style model and Cognitive Trait Model are explained to provide the theoretical underpinning of the current investigation.

2.1 Felder-Silverman Learning Style Model

While there are several learning style theories, Felder-Silverman Learning Style Model (FSLSM) [5] was chosen for this study for the following reason: most other learning style models classify learners into a few broad groups, whereas Felder and Silverman describe the learning style of learners in more detail. It distinguishes between preferences on four bi-polar dimensions: *active* learners learn by trying things out and working with others whereas *reflective* learners learn by thinking things through and working alone. *Sensing* learners like to learn concrete material and tend to be practical whereas *intuitive* learners prefer to learn abstract material such as theories and their meanings and tend to be more innovative than sensing learners. *Visual* learners remember best what they have seen whereas *verbal* learners get more out of words, regardless whether they are spoken or written. *Sequential* learners learn in linear steps and prefer to follow linear stepwise paths whereas *global* learners learn in large leaps and are characterized as holistic.

Each learner has a preference for each of these four dimensions. The preferences are considered to be tendencies indicating that it is possible that learners with a high preference for certain behaviour may sometimes act differently.

2.2 Cognitive Trait Model

The Cognitive Trait Model (CTM) [8] is a student model that profiles learners according to their cognitive traits. The CTM changes the traditional idea of the student model as just a database sitting on the server which is full of numbers for only a particular task. The CTM provides the role of ‘learning companion’, which can be consulted by different learning environments about a particular learner. The CTM can still be valid after a long period of time due to the more or less persistent nature of cognitive traits of human beings [3]. When a student encounters a new learning environment, the learning environment can directly use the CTM of the particular student, and does not need to “re-learn the student”.

Three cognitive traits, working memory capacity, inductive reasoning ability and associative learning skills, have been included in CTM so far. In the current investigation between CTM and learning style model, only working memory capacity is covered, and it is discussed briefly.

In earlier times, working memory was also referred as short-term memory. Richards-Ward [10] named it the Short-Term Store (STS) to emphasise its role of temporal storage of recently perceived information. STS allows us to keep active a limited amount of information (roughly 7+-2 items) for a brief period of time [9]. While Baddeley [1] defined working memory structurally, others defined it as a process [11]. Even though these two different points of views differ on the structure of the working memory, they both agree that the working memory consists of both storage and operational sub-systems [10].

3 Exploratory Study

In [7] investigations about the relationship between FSLSM and working memory capacity (WMC) are presented. Based on the literature, a relationship between high WMC and a reflective, intuitive, and sequential learning style can be identified. In contrast, learners with low WMC tend to prefer an active, sensing, and global learning style. Regarding the visual-verbal dimension, only a relationship in one direction could be identified. Hence, learners with low WMC tend to prefer a visual learning style but learners with a visual learning style do not necessarily have low WMC. On the other hand, learners with verbal learning style tend to have a high WMC but not all learners with high WMC tend to prefer a verbal learning style.

To verify the relationship identified from the literature, an exploratory study with 39 students was conducted. 19 of them are students at Massey University (New Zealand) and 20 are from Vienna University of Technology (Austria). To measure their learning styles, students completed a questionnaire developed by Felder and Soloman [6]. Their WMC was measured by a web-based version of an operation word span task [4, 12] developed for the study. Both instruments are described in the following section and results are presented after that.

3.1 Instruments

For identifying the learning styles according to FSLSM, the Index of Learning Styles (ILS) [6], a 44-item questionnaire developed by Felder and Soloman, was used. As mentioned earlier, each learner has a personal preference for each dimension. These preferences are expressed with values between +11 (e.g. strong active preference) to -11 (e.g. strong reflective preference) per dimension.

Regarding WMC, we developed a web-based version of the operation word span task (OSPAN) [12], Web-OSPAN. Procedures of GOSPAN [4], a computerized and group-administratable operation word span task, were adopted into Web-OSPAN. In the task, subjects are required to perform simple arithmetical operations such as (2 * 3) + 4 = 10. After each operation, a word is presented. The subjects are asked to answer true or false to a group of arithmetic operations and at the end asked to recall the words presented after each operation.

As proposed by Turner & Engels [12], the total number of correct calculations, the total number of correct recalled words, and the maximum set size the subject had the words recalled correctly are recorded and the total number of correctly recalled words is used as a measure of WMC. Both GOSPAN and Web-OSPAN follows OSPAN [12] in recording these measures.

3.2 Results

The data collected from the Web-OSPAN task and the ILS questionnaire were analysed and the results of this analysis are presented in the following.

Visual/Verbal Dimension. From the described relationship between the visual/verbal dimension and WMC, two conclusions can be drawn: (1) learners with a low WMC tend to prefer a visual learning style (but learners with a high WMC prefer either a visual or a verbal learning style) and (2) highly verbal learners tend to have a high WMC (but visual learners can have either high or low WMC).

Because our dataset includes only 2 students with highly verbal learning style, at this stage of analysis it is not possible to draw any reliable conclusions from these two students.

To answer the first statement, only the visual part of the dimension was analysed. The hypothesis to be tested was whether the learners with a low WMC have a highly visual learning style. The significance level is set to 5 %.

The variance for the LWMC group is 10.07 and that of the HWMC group is 12.54. A 1-tailed t-test with unequal variance was used. The T-Stat value 1.77 is greater than that of the critical value 1.69, with significance level at 0.04, indicating that the difference in visual preference is statistically significant. With the positive T-Stat value, the mean of the LWMC group is larger than that of the HMWC group, and it further confirms that learners with low WMC have a highly visual learning style.

Sensing/Intuitive Dimension. Before testing the relationship, an internal consistency reliability test for the questions of ILS was performed. In the sensing/intuitive dimension, three questions were stated as unreliable and therefore were removed them from further analysis. Hence, the instrument became more reliable and accurate.

As discussed earlier, the literature refers to a correlation between a sensing/intuitive learning style and WMC, indicating that sensing learners tend to have a low WMC and intuitive learners are more likely to have a high WMC. According to the regression analysis, this trend can be seen but according to the conducted Pearson correlation at the 0.05 level, there is only a significant correlation between a sensing/intuitive preference and the time students needed to perform the task (r=-0.35).

Looking at the data and the subjects' characteristics in more detail, it can be seen that there are differences in language skills. Especially for the Web-OSPAN task, where students have to remember words, good language skills are crucial. The task was conducted in German for Austrian students and in English for New Zealand students. While all Austrian students have very good German skills, the English skills of New Zealand students varied quite markedly. Only a few students were native speaker and at least half of them had only moderate English skills.

Therefore, the results of the 20 students from Austria were analysed separately. The conducted Pearson correlation results in a significant negative correlation at the 0.05 level to the WMC groups (r=-0.51), the total number of correct recalled words (r=-0.5), and the maximum set size the subject had the words recalled correctly (r=-0.56). Therefore, we can conclude that for the students with good language skills, the expected relationship suggested in the literature is supported.

Active/Reflective and Sequential/Global Dimension. Regarding these two dimensions, no significant evidence supporting the identified relationship to WMC was found. The results of the Pearson correlation test showed no significant correlation. Therefore, further analysis aiming at identifying hidden variables is necessary and a study with a larger sample size is planned.

4 Conclusion and Future Work

In this paper we investigated the relationship between the Felder-Silverman learning style model and working memory capacity, one of the traits in the Cognitive Trait Model. This relationship can be used, on the one hand, to get additional information about learners in systems which are able to detect either learning styles or cognitive traits. For systems that already consider both, learning styles and cognitive traits, the relationship can be used to build a more robust student model by including the information about learning styles in the detection process of cognitive traits and vice versa.

According to current investigations, learners with a high WMC tend to favour reflective, intuitive, and sequential learning styles, and vice versa. On the other hand, learners with a low WMC tend to prefer active, sensing, visual, and global learning styles. To verify this relationship an exploratory study was performed. The relationship between the sensing/intuitive dimension as well as the visual/verbal dimension is supported by the results of the study. For the two other dimensions, no significant correlations were found. This might be because of the small sample size of the study (39 students) or because of the existence of hidden variables.

Future work deals with enlarging the study to get more significant results and also to be able to analyse the results in more detail. Furthermore, we plan to use the benefits of the verified relationships in a web-based educational system which is able to detect learning styles and cognitive traits. The additional information from the relationship will be used to improve the detection process of cognitive traits and learning styles.

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