

# Doctoral Consortium: Integrating Learning Styles into adaptive e-learning system.

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## ABSTRACT

This paper provides an overview and update on my PhD research project which focuses on integrating learning styles into adaptive e-learning system. The project, firstly, aims to develop a system to classify students' learning styles through their online learning behaviour. This will be followed by a study on the complex relationship between learning styles, learning supports and learning outcomes. The findings can contribute significantly to the area that is still left with several unanswered questions. In addition, based on the results, meaningful recommendations and suitable online adaptation can also be made to a wide range of stakeholders of the education system.

## Keywords

Learning Styles; E-learning; Adaptive learning system; Data mining; Learning analytics.

## 1. INTRODUCTION

Learning styles which are defined as students' preferred ways to learn can play an important role in the development of the e-learning system. With the knowledge of different styles, the system can offer insights and advices to a wide range of stakeholders such as students and teachers to effectively organise their learning materials and studying activities to optimise the learning paths. For example, under Felder-Silverman's learning styles frameworks [5], students may prefer to process information actively or reflectively. For "active" students, they perform better through interaction with other students compared to the traditional classroom. Thus, it is advisable for teachers to provide such group the opportunity to interact and discuss the learning topic [5]. A recent report by Thalmann [17] surveying e-learning system developers even suggested that learning styles were the most useful personalization sources among other factors such as background knowledge and user history. In addition, there are clear potential benefits for both fields of learning styles research and e-learning system development. On one hand, the integration can help to improve the e-learning experience, providing means to build rules for personalising resources. On the other hand, the e-learning system which allows data mining and computerized algorithms can offer opportunity to observe, analyse and gain further information into students' learning styles throughout the whole learning process which could not easily be done in traditional learning styles theories research.

Nevertheless, integrating the traditional theories which have the base in psychology, pedagogy and cognitive research into the online environment is not a straight forward task. Measurement methods provided by traditional theories are mostly based on long self-judgment questionnaires [4] and thus, do not provide sufficient means fitting to the e-learning system. Furthermore, scholars still do not agree on how to optimize the matching process between learning styles and learning supports [4, 16] which leaves places for further exploration.

With the motivation to address these research problems of integrating learning styles into adaptive e-learning system, this paper contains my proposals as well as the current research progress.

## 2. PROBLEM STATEMENT AND PROPOSED CONTRIBUTIONS

### 2.1 Research Questions

In a more comprehensive way, learning styles, according to Keefe [11], can be defined as: "The composite of characteristic cognitive, affective, and physiological factors that serve as relatively stable indicators of how a learner perceives, interacts with, and responds to the learning environment". On the traditional theories side, which is mainly based on psychological, pedagogical and cognitive research, the review by Coffield, Moseley, Hall, and Ecclestone, [4] has identified over 70 theories and models. While there are no theories that outperform others [4], theories that consider the flexibility and changes of styles overtime appear to be more popular in e-learning application. Notable theories in this group include: Felder-Silverman's learning styles theory [5] which divides learners based on their: information input, information process, perception, and understanding, Kolb's Learning styles inventory [12] and Honey and Mumford's Learning styles [10] which both divide styles based on their proposed learning cycles.

The theories undoubtedly provide an essential foundation for learning style research. Nevertheless, there are several unsettled issues when applying to the online environment. In this proposal, with the aim to integrate learning styles into e-learning systems, I focus on two main ones: a) learning style classification system in e-learning and b) the relationship between learning styles, learning support and learning outcomes.

#### 2.1.1 Learning Styles Classification

In terms of learning styles measurements, a review by [4] shows that almost all of the theories are assessed by questionnaires or surveys, requiring learners to evaluate or rank their own styles and behaviours. This type of qualitative measurement suffers many downsides. Firstly, it relies on students' self-judgments which can be bias. Secondly, although learning styles, according to many theories, can change over time, surveys and questionnaires only measure styles at one point in time. Several surveys are, in addition,

questioned by critics in terms of validity and reliability [4]. It is time consuming as there are surveys that can reach over 40 - question long (e.g. [16, 23]), and as a result, they may not be updated easily. Hence, these disadvantages of a long, time consuming, and self-judgement-based measurement create several difficulties when it comes to the adaptive e-learning system development.

In recent years, the application of machine learning which allows computerized algorithms to quickly analyse and mine huge online behaviour dataset provides the opportunity to develop new measurement methods that overcome the current drawbacks. As a result, it has opened a call for integrating learning styles with e-learning system using machine learning application [1, 14].

With the area is still at its early stage, there is still only a few proper peer-reviewed researches that attempt to tackle this theories integration issue [1]. Numerous problems remain unanswered. Firstly, several learning styles predictors can be traced in previous literature which show a complex relationship between learning styles and online behaviour. For example, to measure learning styles under Felder-Silverman's framework, while [6] used attributes related to forums, chats, exam revision etc., [20] measured using variables related to assessment such as questions answering time, performance on the test, questions checking time etc. Nevertheless, through my literature review of 51 previous papers [18], none of the papers has managed to compare the power of different predictors. The results of such comparisons will very interesting and valuable as it can act as guidelines for future developers and contribute significantly in improving the performance and efficiency of classification models.

Secondly, in terms of machine learning classification algorithms, among 51 papers reviewed [18], the most popular method identified is Bayesian networks (and Naïve Bayes – a special case of Bayesian network) (e.g.[6, 7],) which has the base in Bayes theorem. This type of approach has shown positive results in a number of researches so far. Nevertheless, for Bayes theorem to work, it requires a number of conditional probabilities and the relation network to be identified which are not always straight forward tasks. Another popular branch of methods is rules based (e.g. [7, 20]). This group of methods is interpretable, however, it relies heavily on how well the researchers “translate” the theory into the online world. For example, Graf et al., [8] based on the description of learning styles from Felder and Silverman's to obtain “rules” e.g. If a student used exercise more frequently, he is more likely to prefer active learning style. The remaining group of researchers still focuses mainly on single supervised methods which left places for the application of other advanced machine learning methods such as hybrid and ensemble machine learning that combine different machine learning algorithms together. Such advanced methods have shown significant higher performance than single algorithm in other applications such as medical and finance ([3, 19]).

Finally, current models also lack generalisation ([2, 15]). Researches are still employed to only one particular context. Akbult and Cardak [1] pointed out that the research population for almost all of the researches is still limited to undergraduate students. Thus, it raises the question if such models can be applied to a different situation from their own.

These open gaps for a better classification model found in learning styles research field have led to the following research questions:

- How can we incorporate machine learning and traditional learning styles theories? How can we measure learning styles through online behaviour?
- Which predictors are the most meaningful in predicting learning styles in online environment? What is the relationship between online behaviour and learning styles?
- What is a more effective way for learning styles classification compared to current approaches?
- Is it possible to generalize the measurement method?

### *2.1.2 The relationship between learning styles, learning support and learning outcomes.*

The second issue relates to the relationship between learning styles, learning supports methods and learning outcomes. On one hand, students with different learning styles prefer to study in different ways. On the other hand, researchers still do not agree on how to optimise this matching process between learning styles and learning supports and interventions ([4, 16],). At the same time, the relationship between learning styles and learning outcomes is still unclear [1]. Pashler, McDaniel, Rohrer and Bjork [13] reported that previous researches still show flaws in their methodology, which as the result, fail to persuasively show the effect of learning instruments on students with different learning styles. There are also several contradictory results. For example, Ford and Chen (2001 cited in [4]) suggested that matching students learning styles with their preferred teaching style is associated with better learning results. However, Holodnaya [9] found that it will be beneficial to study under a mismatched condition. Consequently, to be able to provide reliable feedback to different stakeholders of the education system, it is essential to revisit the issue. The following research questions have been raised:

- How can we match learning supports to learning styles to improve learning outcomes?
- Under the same condition, are learning styles making any differences to learning outcomes? Are there any styles that are more preferable under certain circumstances?

## **2.2 Potential contributions**

Overall, the area of integrating learning styles theories into e-learning systems has gained interest over the past years, yet there are still many questions that are underexplored. This research, thus, firstly, will address a number of research gaps in the field such as the relationship and influence of different online attributes on learning styles. Interesting patterns between different styles and behaviours can, as the consequence, be identified. Secondly, it aims to advance in the methods for learning styles classification which will improve the accuracy and efficiency. Lastly, it will reconfirm the debate in terms of the relationship between learning styles, learning outcomes and learning supports that can contribute significantly in helping the students to excel in their study. In addition, the findings can also work as guidelines and contribute for future e-learning development research.

## **3. PROPOSED METHODS AND CURRENT PROGRESS**

The research will be carried out in 2 phases that each dedicates to a problem mentioned in section 2. At the current stage, I focus on phase 1 which is to develop a learning styles classification system. Thus, this section will centre mainly on phase 1's method and updates.

To develop a classification method, the following process will be carried out: it will start off with learning style theories selection, then attributes selection and finally, classification methods development and evaluation.

Firstly, while the learning styles classification field is crowded [4], through careful review in terms of theories reliability, validity, usefulness in recommendation, in this study, I chose to follow Felder-Silverman theory which is one of the most popular theories implemented in e-learning system [1]. Hence, it will also provide the opportunity for performance benchmarking.

In terms of attributes selection, I have carried out a literature-based survey [18] focusing on not only previous personalization system development researches, but also papers studying the relationship of learning styles and online behaviour. The result is a long list of potential attributes (over 80 items) which can be divided into three main sources including static data such as user background, ethnics, major etc., online behaviour e.g. time spent on certain activities and other personalization sources e.g. intelligence, memory capacity.

The data for different attributes is currently being programmed and collecting for classification methods development using a learning system developed at Corvinno called STUDIO. Felder-Silverman's ILS survey has also been carried out as it is still the base line for online modelling evaluation that has been used in almost all of the previous papers. Over 250 undergraduate students are being observed with the plan of collecting data on the second group of students for model generalisation evaluation ability in the next school term in September.

Lastly, the classification methods development is still in the early stage. As most of previous researches still use single classification methods, I see an opportunity to apply more advanced techniques such as ensemble machine learning which combines different single algorithms to improve the performance. This branch of methods has shown to outperform single methods in other applications such as medical and finance.

#### 4. FUTURE DIRECTION AND ADVICES SOUGHT

The research is still at the early stage and thus, there are a number of challenges ahead that I hope the consortium can provide advices on or sharing similar experiments and insights related to:

- Attributes comparison in the case with huge number of attributes and algorithms tested.
- While I will focus on ensemble and hybrid methods, I am also interested in if there is any other method, especially in the area of sequence mining.
- Generalisation: Is this necessary/possible to generalise the detection models? What are the conditions that we have to test for generalisation? Is testing on different populations enough?

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