



Integrating learning styles and adaptive e-learning system: Current developments, problems and opportunities



Huong May Truong

Corvinno Technology Transfer Centre, Eduworks ITN, Kozraktar 12/a, H-1093 Budapest, Hungary

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ABSTRACT

Learning styles which refer to students' preferred ways to learn can play an important role in adaptive e-learning systems. With the knowledge of different styles, the system can offer valuable advice and instructions to students and teachers to optimise students' learning process. Moreover, e-learning system which allows computerised and statistical algorithms opens the opportunity to overcome drawbacks of the traditional detection method that uses mainly questionnaire. These appealing reasons have led to a growing number of researches looking into the integration of learning styles and adaptive learning system. This paper, by reviewing 51 studies, delves deeply into different parts of the integration process. It captures a variety of aspects from learning styles theories selection in e-learning environment, online learning styles predictors, automatic learning styles classification to numerous learning styles applications. The results offer insights into different developments, achievements and open problems in the field. Based on these findings, the paper also provides discussion, recommendations and guidelines for future researches.

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1. Introduction

Different students have different preferred ways to learn. Some may understand quickly through images, others may prefer texts and readings. Some may deal well with theories, others may learn through experiments and examples. By gaining insights into different learning styles, it offers means to design and provide interventions that tailored to individual needs. Moreover, several valuable advice can be provided to a wide range stakeholders. For example, for learners, insights into their own styles will enable them to be more confident in learning and optimize their learning paths (Herod, 2004). For teachers, it will be able to offer valuable feedback on how to match suitable instructions and learning materials to different groups of students at the appropriate stage of the learning process (Stash, 2007). For instance, under Felder–Silverman's theory (Felder & Silverman, 1988), learning styles can be differentiated between the way students process information: active experimentation or reflective observations. For “active” students, they do not perform very well in a standard classroom situation. Conversely, they learn effectively through interaction with other students. Thus, it is advisable for teachers to provide such

group the opportunity to cooperate and discuss the topic. Furthermore, there is evidence in previous researches (such as in Kolb, Boyatzis, & Mainemelis, 2001 and Plovnick, 1975) which shows the connection between learning styles and career choices. Based on this, recommendations and guidance to support the career path planning can be developed. With this strong appeal, learning styles have been gaining significant interest from researchers and educators. Coffield, Moseley, Hall, and Ecclestone (2004), in their review, reported over 70 theories that were developed over the past 30 years.

In a more comprehensive way, learning styles, which according to Keefe (1979) 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”. The crowded theories area can be divided into five groups depending on their assumptions on how flexible the learning styles can change over the lifetime (Coffield et al., 2004). On one extreme, there are theories such as Dunn and Dunn's models and instruments of learning styles (cited in Dunn & Griggs, 2003), which suggests that learning styles are constitutionally based, that is fixed. On the other extreme, researchers consider tactics rather than learning styles. Learning tactics assume that learning behaviours can change depending on

E-mail address: mtruong@corvinno.com

the situation. This branch includes theories such as Entwistle's approaches and study skills inventory for students (Entwistle, 1997), and Vermunt's inventory of learning styles (Vermunt, 1998). Other prominent theories include Kolb's (Kolb, Osland, & Rubin, 1995) and Felder–Silverman's (Felder & Silverman, 1988) which consider learning styles as rather stable indicators but may change over the lifetime.

Traditionally, learning styles are mainly measured using surveys and questionnaires, asking students to self-evaluate their own behaviours. This development is suitable with the traditional classroom where it is difficult to observe and analyse students' preferences over the whole learning process. However, as for every qualitative survey, this type of measurement suffers many drawbacks. Firstly, it can be biased as it depends on students' judgment. Secondly, it is done only at a point in time while the learning styles, according to several theories, can change over time. Some of these surveys can reach over 40-question long (such as Vermunt's (Vermunt, 1998) and Felder–Silverman's (Felder & Silverman, 1988)) and hence, they are not easy to update.

These drawbacks have encouraged a growing number of researchers to integrate the framework of learning styles into e-learning system. On one hand, e-learning system, which allows researchers to observe students' behaviours throughout the learning process and with the use of data mining and computerised algorithms, to quickly identify and analyse trends in big dataset, opens opportunities to develop new framework to observe and measure learning styles through online behaviours. On the other hand, learning styles are also useful sources to develop an adaptive e-learning system that effectively personalises learning resources to individuals' learning needs. With strong appeal, the integration of the IT-related and psychology and pedagogy-related area have gained significant interest over the past years. A recent paper surveying e-learning system developers by Thalmann (2014) even suggested that learning styles models were the most useful frameworks for adaptive system development among other sources such as previous knowledge and student background.

The constructs and applications of learning styles into adaptive e-learning system have observed several positive results in both learning styles detection (such as in García, Amandi, Schiaffino, & Campo, 2007; Graf, Kinshuk, & Liu, 2009; Scott, Rodríguez, Soría, & Campo, 2014; Özpölat & Akar, 2009) and applications (such as personalising learning materials and learning contents as in Kurilovas, Kubilinskiene, & Dagiene, 2014 and developing educational games as in Lin, Yeh, Hung, & Chang, 2013). This paper provides an update and a systematic review on this integration of learning styles into adaptive e-learning system. Through the literature review, it offers insights into different methodologies, constructs, developments and applications that have been studied in the research field. Moreover, broadening from previous reviews such as papers by Vandewaetere, Desmet, and Clarebout (2011) and Akbulut and Cardak (2012) which either only briefly looked at learning styles as part of many other personalisation characteristics or only presented parts of the whole applications, this paper, focusing on learning styles, delves deeply into the integration process. It captures several aspects from learning styles measurement in e-learning system, to the usage of learning styles in e-learning application. Based on the findings, it also provides new insights into current developments, issues and challenges and as the result, valuable recommendations can be offered for future studies.

2. Search methods

Different studies on the integration of learning styles and adaptive learning system reviewed in this paper were collected through three search systems: Google Scholar, Scopus and Science Direct. Articles for the last 10 years (from to 2004 to 2014) were consid-

ered. The search process terminated in November 2014. Comprehensive searches were carried out using a variety of search terms and their combinations including: "learning styles | (or) style", "measurement | classification | prediction | evaluation | modelling | detection | recognition", "adaptive | personalised | individualised | personalisation", "integration | application | using", "automatic", "learning system | learning management system", "intelligent tutoring system", "student | user modelling", "online | e-learning", "computer-assisted learning", "adaptive instructions", "adaptive hypermedia", "artificial intelligent", "education data mining".

The scope of this research surrounds the current application and integration of learning styles theories in adaptive learning system. Hence, the following inclusion criteria was applied: learning styles theory/theories had to be included as part of the design/structure/development/modelling of the e-learning system; there were evidences of implementation (e.g. there was description or demonstration of the actual implementation, or there were evidences of models evaluation/testing). Considering such inclusion criteria, the searches resulted in 51 papers among which 39 were journal papers and 12 were conferences papers. These articles were then analysed, synthesized, and grouped using similar themes. The results are shown in the next section.

3. Results: the current developments

3.1. Classification of results: learning styles integration process

By reviewing previous literature, it was identified that all the articles followed a very similar integration and development process and thus, the results of the analysis are also presented according to this course which is shown in Fig. 1. Through this result classification approach, it can be helpful for future researchers and e-learning system analyst to quickly gain insights into different required parts of the development process.

The process of integrating learning styles into adaptive learning system can be divided into two main areas: learning styles prediction using online data (or the online learning styles classification model) and the application of this model into adaptive learning system. The development starts with choosing the learning styles framework. This is followed by the determinant of data sources and learning styles attributes and classification algorithm selections. After evaluating, the suitable classification models and

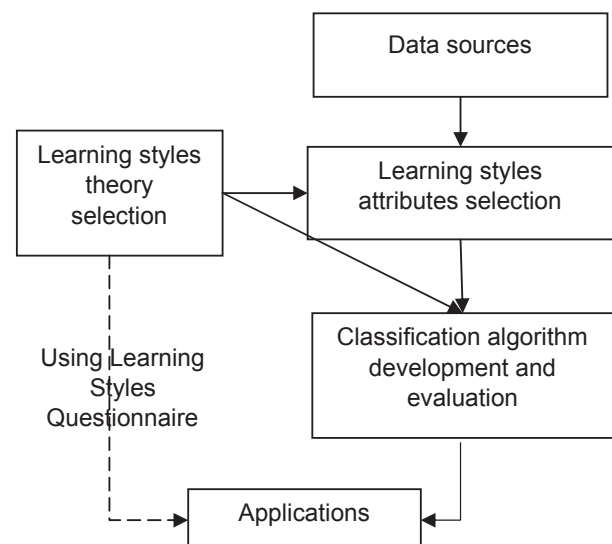


Fig. 1. Learning styles integration process.

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