Personalizing Open Learning Environments through the adaptation to Learning Styles

Heba A. Fasihuddin, Geoff D. Skinner, Rukshan I. Athauda

Abstract—Open learning represents a new form of online learning. It is based on providing Massive Open Online Courses (MOOCs) for free to be taken by any interested learner. It has been found that the current model of open learning suffers from some limitations, and one of these limitations is the lack of personalization. It has also been found that the consideration of learning principles and cognitive science is able to enhance the learning experience in open learning environments. Therefore, this paper aims to introduce an approach to enhance open learning environments and provide personalization based on the consideration of cognitive science. The learning style theory is considered and, specifically, the Felder and Silverman model is selected to identify the learning styles and provide the required adaptation. The paper presents the patterns that can be monitored in the open learning environment to identify the learning styles, and also a description of how the adaptation support can be provided based on the identified patterns.

Index Terms—Adaptive systems, learning styles, MOOCs, open learning, personalization.

I. INTRODUCTION

Online learning is an evolutionary learning approach that keeps evolving and changing due to the continuous evolution of technology. Open learning is a new phenomenon of online learning that allows learning materials to be freely available on the Internet for anyone who is interested. This new phenomenon becomes a tangible reality due to the newly emerged cloud computing technology.

Recently, various prestigious learning institutions, such as Harvard, MIT, and Stanford, have utilized cloud computing to provide learning materials in an open approach. Coursera [1], edX [2], Udacity [3], Udemy [4], and many others are examples of this inventive open learning style. Courses that are provided through these open learning environments are termed Massive Open Online Courses (MOOCs). Despite the popularity of MOOCs and the fact they attract an enormous number of learners [5], there are some limitations that still need to be considered and managed to enhance such an open model of learning. These limitations relate to different aspects of the courses, such as teaching and learning methods; learning content; assessments; identity authentication; accreditation; and learners’ varying needs, among others. All of these limitations raise different concerns about the sustainability of open learning. The authors believe that there is a need to enhance the current model of open learning, and based on the suggestion in [6], they find that this can be done efficiently by considering cognitive science and learning principles. The authors have previously introduced some learning theories that can be considered to enhance the presentation and organization of learning materials in open learning environments, and also to personalize the learning experience and adapt to individual learners’ needs and preferences [7].

The focus of this paper is the personalization of open learning environments based on the theory of learning styles. Learning style refers to the way a learner receives and processes information; therefore, every learner has a different learning style [8]. Among different existing models of learning styles, the Felder and Silverman Learning Style Model (FSLSM) has been selected to be incorporated in open learning environments to provide a personalized learning experience.

The FSLSM has been considered in different studies to provide adaptive learning environments. Some of these studies were based on using the Index of Learning Styles (ILS) [9], which is a questionnaire developed by Felder and Soloman to identify the learning style in order to provide learning objects that suit each learner’s learning style. Other studies were concerned with introducing a mechanism to automatically identify the learning styles. Different approaches were applied and different mechanisms have been introduced in the literature. More details about these approaches will be provided later in this paper. The authors found that the literature-based approach, firstly introduced by Graf in [10] and mainly based on monitoring the learners’ behaviors on some determined patterns based on the FSLSM, had higher accuracy results in detecting learning styles. Therefore, it has been proposed to apply this approach to automatically identify learning styles and personalize open learning environments.

This paper aims to introduce some patterns that are able to provide hints to identify learners’ learning styles based on the FSLSM in open learning environments. These patterns are determined based on the learning objects that are common in some open environments, such as edX, Coursera, Udemy, and Udacity. The proposed model is designed in such a way that it considers the learning objects in open learning environments, and that what makes this study differ than other studies that care about blended learning environments. The rest of this paper is organized as follows: first, a background of open learning and contemporary Massive Open Online Courses is provided in section 2. Section 3 provides an overview of
adaptive systems with respect to learning styles. Section 4 presents a review of previous work on adaptive systems based on learning styles. The application of the FSLSM to open learning environments and the determined patterns of behaviors to identify the learning styles are presented in section 5. Finally, the paper is concluded in section 6 with a brief overview of planned future work.

II. BACKGROUND

As mentioned, the evolution of technology leads to continual change and development in online learning approaches, and recently, open learning has emerged as a new form of online learning based on the utilization of cloud computing capabilities. In open learning, resources are freely available on the Internet to be accessed by anyone who is interested. These resources are provided by different learning providers who could be academics representing learning institutions or individuals who have appropriate knowledge and expertise. The provided resources have been termed “open educational resources” and have been defined by UNESCO as “technology-enabled, open provision of educational resources for consultation, use and adaptation by a community of users for non-commercial purposes. They are typically made freely available over the Web or the Internet. Their principal use is by teachers and educational institutions to support course development, but they can also be used directly by students. Open Educational Resources include learning objects such as lecture material, references and readings, simulations, experiments and demonstrations, as well as syllabi, curricula and teachers’ guides” [11].

Recently, many academics have changed their practice by publishing their learning materials online, thus allowing their expertise to be accessed in open educational resources. This practice has gradually refined into what are known as Massive Open Online Courses (MOOCs).

MOOCs offer free university-level courses online and have two key features – open access and scalability [12]. These two features allow MOOCs to be taken online by anyone and enable the courses to be designed to support an indefinite or even infinite number of participants. They are learner-centered courses, so learners are able to work and learn at their own pace, which gives learners the opportunity to maintain their peak cognitive level and ability as they are able to access learning resources repeatedly until they meet their learning needs.

MOOCs are a current point of controversy, and their success cannot yet be determined. There are some limitations of MOOCs that make them a point of contention. These limitations relate to various factors including accreditation, authentication, teaching methods, and subjects that can be taught in such a way [13]. Moreover, it has been claimed that MOOCs place less emphasis on providing interactive and dynamic approaches to learning, as there is no creativity in delivering learning content, only the use of traditional approaches (i.e. video lectures) that lack support for learners’ variable needs [14].

Based on the highlighted dilemmas, the authors believe that there is no clear frontrunner in terms of a model for MOOCs or open learning environments. Rather, MOOCs and other open learning initiatives are in their early stages of evolution. Different aspects and research questions still need to be considered and addressed in order to achieve a valid model [7]. However, there is the possibility that a single model might not be a solution to all learning needs and environments, and a plethora of models and systems may emerge catering to differing learning needs and environments.

The development of open learning environments is a critical and sensitive field due to the implications they have on learners, instructors, and the learning process. Therefore, scientific principles for learning should be considered in the development of MOOCs in order to achieve the desired learning goals. It is stated in [6] that tailoring general learning principles and working with cognitive scientists is one approach that needs to be considered to enhance MOOCs and provide the best outcomes for learners. Based on this, the authors consider the theory of learning styles [8] to introduce an approach for personalizing open learning environments. This is believed to increase learners’ satisfaction and lead to better learning outcomes.

III. ADAPTIVE SYSTEMS WITH RESPECT TO LEARNING STYLE

Currently, open learning environments are based on the “one size fits all” approach. There is no personal support or consideration of individual needs and preferences. As open learning environments target a massive number of learners with different backgrounds, preferences, and cognitive abilities, adaptability to the variability of learners’ needs and preferences is crucial. Brusilovsky described adaptive systems as the system’s ability to provide personalized learning support to the learner throughout their interaction with the system based on the goals, preferences, and knowledge of each individual learner [15]. It has been found that adaptive learning systems lead to better learning outcomes, reduce time and effort required, and increase learners’ satisfaction [16]. Adaptive systems can adapt to user data, usage data, and environments data [15]. User data refers to various characteristics of the user, such as learning styles and cognitive traits. Usage data refers to user interaction with the systems. Environment data refers to the adaptation to user context, including location or platform. Providing adaptability based on the considered factors has been classified into two different areas – adaptive presentation and adaptive navigation support [15]. Adaptive presentation comprises text and multimedia adaptation technologies, while adaptive navigation support comprises links sorting, hiding, annotation, and direct guidance.

Open learning environments can be personalized and provide adaptable support based on any of the previously presented adaptability methods and techniques. However, the authors’ focus in this paper is to present a model to personalize open learning environments based on the adaptability to learners’ learning styles. This model aims to provide adaptive navigational support to individual learners based on their preferred learning style. Following is an overview of what learning styles are and how they can be considered in order to personalize open learning environments.
### A. Learning Styles

Learning style refers to the way a learner receives and processes information [8]. Therefore, different learners have different learning styles [8]. Considering learning styles in the courseware design has been found to be effective and beneficial in learning. It has been stated that providing learners with learning materials and activities that suit their preferences and learning styles makes learning easier for them [17]. This statement has been proven by many studies that found that students can achieve better learning outcomes and higher scores [18], and can also master the learning materials in less time [19].

In the literature, several models for identifying learning styles were defined and found to be valid and reliable [20]. However, the Felder and Silverman Learning Style Model (FSLSM) is selected to be applied to personalize open learning environments [8]. This selection is based on recommendations in the literature. The FSLSM was mainly proposed for engineering education, and according to Felder, the original paper of their proposed model was the most frequently cited paper in articles published in the Journal of Engineering Education over a 10-year period. In addition, the mechanism of its Index of Learning Style (ILS) questionnaire that was developed by Felder and Soloman to identify learning styles can be easily applied to adaptive systems [9]. Furthermore, it has been stated that the FSLSM is the most appropriate and feasible model to be implemented in adaptive courseware [21, 22]. Moreover, a study that was conducted to compare the suitability of different learning style models to be applied in online learning concluded that the FSLSM is the most appropriate model. This is because it provides more details that enable it to be tailored to individual needs and preferences, providing adaptability [23]. Considering this, the authors hypothesize that such a model will be effective in online learning and particularly in open learning.

The FSLSM classifies learning styles into four dimensions and identifies two types of learners for each dimension. The dimensions are perception, input, processing, and understanding. Firstly, the perception dimension defines the type of information that learners prefer to receive and learn by: intuitive learners prefer meaning and theories, while sensory learners prefer learning by examples and practice. The second dimension is input, which defines the approach the learners prefer to learn with; visual learners prefer pictures, diagrams, and flowcharts, while verbal learners prefer written or spoken explanations. The processing dimension indicates how learners prefer to process and practice their learning; active learners prefer working with others, while reflective learners prefer thinking and working alone. Finally, the understanding dimension indicates how learners progress toward understanding; sequential learners learn in continual small steps, while global learners learn holistically in large jumps. Table I represents these learning styles and their associated types.

![Table I](image)

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Preferred Learning Style</th>
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<tbody>
<tr>
<td>Perception</td>
<td>Sensory</td>
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<tr>
<td>Input</td>
<td>Visual</td>
</tr>
<tr>
<td>Processing</td>
<td>Active</td>
</tr>
<tr>
<td>Understanding</td>
<td>Sequential</td>
</tr>
</tbody>
</table>

### B. Methods for Adapting to Learning Styles

Systems that are adaptive to learning styles need to identify the learner’s learning style first and then adapt to the learner’s preferences. Adaptation methods of adaptive systems have been classified into two different approaches – collaborative and automatic [24]. In the collaborative approach, learners are asked to provide their preferences explicitly by taking a test or filling out a questionnaire, such as the ILS questionnaire [9], in order to build their adaptable models. On the other hand, in the automatic approach, the learners’ adaptable models are built automatically by the adaptive systems through intelligent and machine learning techniques that exploit learners’ interactions and behaviors while they are using the systems for learning.

In the literature, two different methods for identifying learning styles based on the FSLSM were used – the data-driven method and the literature-based method [10]. Both methods rely on some identified patterns to detect the learning style of the learner. These patterns are based on monitoring the provided learning objects in such a way that they adhere to the FSLSM. The data-driven method aims to build a model that imitates the ILS questionnaire and uses sample data to construct a model. Some of the techniques used to apply this method are neural network, decision tree, Hidden Markov Model, fuzzy clustering, and Bayesian network. The literature-based method uses the behavior of students and actions with the systems while they are learning in order to identify their learning style preferences. It is entirely literature-based, as patterns are identified based on findings of learners’ preferences and behaviors for each specific learning style. This method uses only simple rule-based methods to calculate learning styles. A study has been conducted to compare the efficiency of these two methods in detecting learning styles, and has found that the literature-based method gives more accurate results than the data-driven method [10]. Although the literature-based method has been found to be efficient, it has been claimed in [25] that this method’s point of weakness is embodied in the possibility of not considering all the potential patterns that could affect the detection of learning styles. Based on this, the identification of learning styles in open learning environments should consider all the potential patterns on the provided learning objects in these environments.

### IV. REVIEW OF RELATED WORK

Building adaptive systems that adapt to learners’ learning styles has been a point of interest in the research. Different studies have been done to provide adaptive learning based on learning styles. Some of these studies were based on the collaborative adaptive approach, where students were asked to provide their preferences through the answers to the ILS questionnaire; while others were based on the automatic
V. INCORPORATING THE FSLSM INTO OPEN LEARNING ENVIRONMENTS

A. Patterns to Identify Learning Styles

Determining patterns for identifying learning styles in open learning environments should be based on the learning objects in these environments. For that, the authors have observed the provided learning objects in some of the well-known MOOCs, such as edX [2], Coursera [1], Udemy [4] and Udacity [3]. The identified learning objects include course overviews, outlines, video lectures that are supported with scripts in some MOOCs such as in edX, number of learning objects that vary between textual-based and visual-based, discussion forums, examples, exercises, quizzes with immediate feedback, and additional reading materials. Monitoring the learners’ interactions and behaviors with these different learning objects leads to identifying the learning styles and consequently provide and organize the learning materials based on the learners’ preferences.

Felder and Silverman have presented a good explanation for the FSLSM in terms of learners’ preferences and the corresponding learning and teaching styles [8]. Considering this and other literature [25, 32, 36, 38, 41], the authors have determined patterns to identify learning styles in open learning environments; these patterns consider the previously listed learning objects. In addition, knowledge maps have been considered as a learning object, and this is based on our previously published suggestion of organizing learning concepts in a knowledge map as an approach to enhancing the learning experience in open learning environments [7][42].

To identify the preferred learning styles for each dimension, certain patterns of behaviors need to be monitored. Following are descriptions of these patterns of behaviors. First, in terms of learners’ perceptions, sensing learners prefer facts, data and experimentation (i.e. concrete materials), while intuitive learners prefer principles and theories (i.e. abstract materials), so annotating the learning objects to specify their types (i.e. concrete and abstract) and the learners’ access to these objects and the time spent on them can be used as a pattern. In addition, sensing learners like to solve problems by standard methods and do not like surprises, while intuitive learners like to invent new ways to solve problems. Based on this, sensing learners are expected to access more examples and spend more time on them, while intuitive learners spend more time on the learning materials. These can be considered other patterns to distinguish between sensors and intuitors. Sensing learners are patient with details, careful but slow, while intuitive learners tend to be quick and careless: therefore, sensing learners spend more time on quizzes while intuitive learners spend less time.

In regards to the Input dimension, visual learners remember what they see better than what they listen to or are told, while verbal learners remember more of what they hear than what they see. Visual learners learn better by diagrams, flowcharts, pictures, and demonstrations, while verbal learners prefer verbal explanation rather than visual demonstration. Therefore, annotating the learning objects to distinguish whether they are visual or verbal, and the access and time spent on them, can be considered a pattern.

In regards to the processing dimension, active learners like to try out and learn by practice, while reflective learners prefer to think and reflect about what they learn, so they learn better by observation. Based on this, active learners tend to access more examples and exercises and spend more time on them. In addition, active learners like to work in groups, while reflective learners prefer to learn alone; therefore, active learners access the discussion forums and posts more than the reflective learners.

Finally, in regards to the understanding dimension, sequential learners like to learn in a sequential process and prefer learning materials to be organized and presented in a steady progression of complexity and difficulty. Global learners do not like the linear approach and might jump...
directly to the more complex materials. Based on this, the behavior of accessing the learning materials can be considered as a pattern. In addition, global learners like to be provided with the overall picture of the provided topic; therefore, they access and spend more time on the overview and outline. Moreover, global learners are expected to access the knowledge maps of the learning concepts more than the sequential learners, so the time spent on accessing the knowledge maps is another pattern. Furthermore, the findings of [39] can lead to another pattern to distinguish between the global and sequential learners. This study has found that the mouse maximum vertical speed for global learners is higher than for sequential learners. Table II summarizes all the mentioned patterns to identify learning styles in open learning environments.

<table>
<thead>
<tr>
<th>TABLE II</th>
<th>Patterns for Identifying Learning Styles in Open Learning Environments</th>
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<tbody>
<tr>
<td>Sensing learners</td>
<td>Intuitive learners</td>
</tr>
<tr>
<td>Example access (+)</td>
<td>Example access (+)</td>
</tr>
<tr>
<td>Example time (+)</td>
<td>Example time (+)</td>
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<tr>
<td>Exercise access (+)</td>
<td>Exercise access (+)</td>
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<tr>
<td>Exercise time (+)</td>
<td>Exercise time (+)</td>
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<tr>
<td>Details and concrete learning objects time (+)</td>
<td>Details and concrete learning objects time (+)</td>
</tr>
<tr>
<td>Abstract learning objects time (-)</td>
<td>Abstract learning objects time (+)</td>
</tr>
<tr>
<td>Additional reading access (+)</td>
<td>Additional reading access (-)</td>
</tr>
<tr>
<td>Quiz time (+)</td>
<td>Quiz time (-)</td>
</tr>
</tbody>
</table>

Visual learners
- Visual learning objects access (+)
- Visual learning objects time (+)

Verbal learners
- Visual learning objects access (-)
- Visual learning objects time (-)

Active learners
- Exercise access (+)
- Exercise time (-)
- Example access (+)
- Example time (-)
- Forum access (+)
- Forum Post (+)

Reflective learners
- Exercise access (-)
- Exercise time (+)
- Example access (-)
- Example time (+)
- Forum access (-)
- Forum Post (-)

Sequential learner
- Outline access (-)
- Outline time (-)
- Access the topic knowledge map (-)
- Linear access for learning concepts (+)

Global learners
- Outline access (+)
- Outline time (+)
- Access the topic knowledge map (+)
- Linear access for learning concepts (-)

B. Providing Adaptive Support Based on the Identified Learning Styles

The adaptation to the learners’ identified learning styles is proposed to be provided through navigational support. This means that every learner will get the learning objects organized in such a way that suits their learning style. This organization will be based on the recommendations in [8, 19]. As mentioned, sensing learners prefer to learn from concrete materials, so these types of learning objects need to be shown before the abstract materials. The opposite needs to be done for intuitive learners – abstract materials need to be shown to them first. In addition, sensing learners prefer to learn by examples and real-life applications, so examples need to be shown to them before the explanation, while intuitive learners prefer the reverse. Moreover, sensing learners prefer to get more examples and exercises, so all the available examples and exercises need to be recommended to them, while just some can be recommended to intuitive learners. In terms of the input dimensions, textual-based learning objects can be recommended to verbal-based learners, while the visual-based objects can be recommended to the visual learners. For the processing dimension, active learners prefer to learn by doing, so more exercises will be provided to them in between the learning material. They also like to invent their own approaches to solving problems, therefore, fewer examples will be shown to them. The reverse approach needs to be taken for reflective learners, so more examples will be shown in between the learning objects and less exercises. In regards to the understanding dimension, sequential learners prefer to learn by a linear approach, so learning objects involving examples and exercises need to be organized in a linear increase of complexity, and the course conclusion and knowledge map are to be shown last. In contrast, the conclusion and the knowledge map need to be presented first to global learners.

Providing learning objects in the previous described organization is believed to enhance the learning experience in open learning environments and consequently enhance the learners’ satisfaction and learning outcomes.

VI. CONCLUSION AND FUTURE WORK

This paper introduces an approach to enhance the learning experience in open learning environments, where Massive Open Online Courses (MOOCs) are provided for free and taken by learners at their own pace. It has been found that many aspects still need to be considered and addressed in order to achieve an effective sustainable model of MOOCs; one of these aspects is the lack of personalization and adaptability. It has also been found that cognitive science and learning principles can be applied to maximize the outcomes of MOOCs and increase their opportunity to become sustainable models for learning. Based on this, the theory of learning styles, and particularly the FSLSM, has been selected for application to provide personalized learning.

This paper presents the FSLSM as an approach to personalizing open learning environments. The literature-based method has been found to give better results in identifying the learning styles [36], and therefore it was proposed to take this method. The paper introduces the patterns of learners’ behaviors that can be monitored to identify learning styles. These patterns are determined based on the provided learning objects in open learning environments. In addition, a description of how to provide adaptable navigational support is also provided.

Future work of this study involves developing a prototype that simulates open learning environments in terms of offering open online courses that learners can take and learn at their own pace. This prototype will be dynamically adaptable to learners’ learning styles based on the presented patterns, and will also provide individual navigational support. In addition, evaluations of the precision of identifying learning styles and the learners’ satisfaction about the provided adaptability will be done.