Towards Automatic Flow Experience Identification in Educational Systems: A Theory-driven Approach

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Flow experience definition: The notion of "flow experience" or "flow state" was introduced by Csikszentmihalyi [2] as a technical term to describe a good feeling or "optimal experience" that people have as a motivating factor in their daily activities, such as at work, in sports, and in artistic performance [10]. The main aspect to understand the flow state is the "autotelic experience" concept, that is an experience that produces intrinsic motivation, a feeling of self rewards, or incentives, specifically without any outside goals or external rewards [26].

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Abstract

Flow is a state of deep engagement that is highly related to the learning experiences. One of the biggest challenges in this field is to provide automatic and implicit students' flow experience identification in educational systems, contributing to the educational systems design and evaluation improvement. In this paper, we propose a theory-driven based conceptual model, associating student's interaction data logs with each of the flow experience dimensions, towards the automatic flow identification. The main result indicates that eight different kinds of data logs can be associated with the nine original flow experience dimensions and provide the automatic students' flow experience identification. As a future study, we aim to design an educational system capable of obtaining student's data logs conducting a data-driven based study to validate our theoretical study.

Author Keywords

flow theory; flow experience; automatic identification; user interaction; educational systems.

CCS Concepts

•**Human-centered computing** → **Human computer interaction (HCI);** *User studies;* HCI theory, concepts and models;

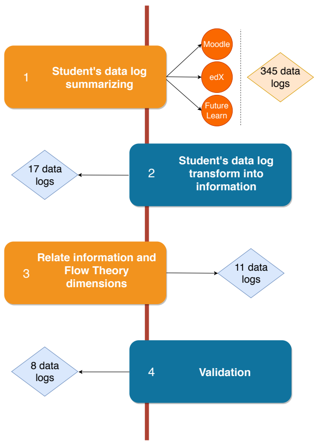

Figure 1: Study organization

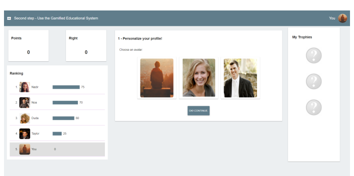

Figure 2: Interface example 1

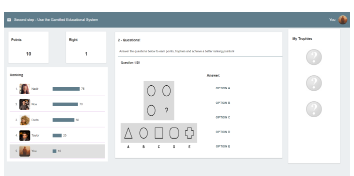

Figure 3: Interface example 2

Introduction

Flow, defined by the Hungarian-American psychologist Mihaly Csikszentmihalyi [6], describes an optimal experience of intense engagement that can occur when people are immersed in certain activity [4, 22, 5]. Flow is intrinsically related to the learning experience [3, 30, 14, 15, 1], and, when in this state, there is a greater chance that the student will reach a better learning experience [4, 30, 24].

In educational systems, Flow is highly related to the user experience (UX), as well as the students' learning experience [28, 19, 12], because the better the user experience in the system, the greater the chances for the student to achieve a flow state and consequently, to have a better learning experience [5, 15, 19].

Currently, there are two flow measurement approaches, one during the performance of an activity and the other after performing an activity [22], and according to different literature review studies [29, 26], the vast majority of studies on flow in educational settings use extensive questionnaires, user experience reports, or body-coupled devices (*e.g.*, electroencephalograms (EEG) or eye tracking) to measure the students' flow experience in the educational systems.

On one hand, we can observe the utility of these approaches to measure the flow, on the other hand, we can observe that these same approaches also remove the students from the flow, by removing them from their actual experience to answer the questionnaires (intrusive method) [27, 29, 26]. In view of these problems and the large amount of interaction data (data logs) generated by user interactions in the systems, one of the contemporary big challenges is to design a way to provide an implicit and automatic students' flow experience identification in educational systems, based on real data from the student interaction in the systems [26].

Based on the exposed, this study aims at answering the following research question "How could we measure Flow using non-intrusive methods?". We focus on answering this question by conducting a theoretical study focused at identifying automatically the students' flow experience through the association between students' interaction data logs and the nine original flow experience dimensions proposed by Csikszentmihalyi [2].

To validate our proposal, we conducted a study based on experts opinion, and provided an artificial validation through the simulation of application of the approach in a real system. The main results indicate that there is a relationship between eight interaction data logs (*e.g.*, amount of time using the system and proportion of correct responses in required activities) produced by the users and their flow experience in the system. The main contribution of this work is a conceptual model on how to use learning systems data logs to measure the students' flow experience.

Background and Related Works

This section aims to present a literature review on the main topic related to this study. We also will present in this section the main related works.

Flow Theory, Learning and Human-computer Interaction

Since the Csikszentmihalyi' Flow Theory emergence, many different studies have been conducted to discuss the flow experience concept. For example, Csikszentmihalyi [6, 2, 4] describes nine necessary dimensions to prompt the flow state of a person: (1) challenge-skill balance; (2) action-awareness merging; (3) clear goals; (4) unambiguous feedback; (5) total concentration on the task at hand; (6) sense of control; (7) loss of self-consciousness; (8) transformation of time; and (9) *Autotelic* experience.

Found information analyzed by the experts: *(i)* Active time in the system; *(ii)* Used time to finish a step/activity; *(iii)* Proportion of correct steps; *(iv)* Proportion of help requests; *(v)* Proportion of answers that were incorrect and received bug messages; *(vi)* Average response time; *(vii)* Proportion of slow and/or fast responses after a bug message; *(viii)* Proportion of slow and fast responses after requesting a hint; *(ix)* Proportion of slow responses after receiving a hint and entering a correct answer; *(x)* Number of mouse click out of buttons; *(xi)* Total unique session views.

Most recent, Hoffman and Novak [18] summarized the original dimensions proposed by Csikszentmihalyi into five dimensions: (1) enjoyment; (2) telepresence; (3) focused attention; (4) engagement; and (5) time distortion. Rodriguez-Sanchez and Schaufeli on the other hand, simplified into just three dimensions: (1) absorption, (2) enjoyment, and (3) intrinsic interest. Despite these studies, the original nine dimensions proposed by Csikszentmihalyi are still the main references on the flow experience [5, 29, 26]. Therefore, with the aim of encompassing all original and commonly used dimensions, we decided to use the nine original dimensions. Next, we will present a definition for each of the dimensions (summarized of Jackson *et al.* [21]):

1. Challenge-skill balance: when experiencing flow, a exists dynamic balance between challenges and skills [21]. **2. Action-awareness merging:** illustrates the idea of growth in complexity that results from flow experience [21]. **3. Clear goals:** a necessary part of achieving something worthwhile in any endeavor (including the flow experience) [21, 22]. **4. Unambiguous feedback:** when receiving feedback associated with a flow state, the individual does not need to stop and reflect on how things are progressing [21]. **5. Total concentration on the task at hand:** in contrast to one's usual experience, no effort is required to keep the mind on task when in flow [21, 6, 7]. **6. Sense of control:** like flow itself, the sense of control often lasts only for a short period of time and this relates to keeping the challenge-skill balance within a situation [21]. **7. Loss of self-consciousness:** represents the sense of self-reflection about the things that happen through the moments [21]. **8. Transformation of time:** when the time transformation is experienced, it is one of the liberating dimensions of flow (to feel free from the time dependence under which we live most of our lives) [21]. **9. *Autotelic* experience:** it is generally after completing a task, upon reflection, that the *autotelic* aspect of flow is realized and provides high motivation toward further involvement [21][1]. Some of these factors are also classified as "flow antecedents".

In educational systems, the flow experience is highly linked to the learning experience, because when in flow, the student tends to have a better and more enjoyable learning experience [3, 30, 14, 15, 1, 16, 20, 9]. Understanding these pillars is important to relate them to the UX. According to Kasper and Morten [19], the system design can affect directly the students' flow state and if it is possible to perceive that a students' flow experience is not high, different aspects of the system can be changed to lead users to better experience.

When an individual achieves one or more of these experiences, we can say that this individual has attained some components of the flow experience. However, only when an individual manages to attain the nine dimensions, we say that this individual has had a real flow experience [23]. These nine dimensions will be used as the basis for our entire conceptual model, which relates the user's data logs to each of the dimensions.

Related works

To identify our related works and the main challenges in this field, we conducted a systematic literature review (see Oliveira *et al.* [26]). Although the community considers automatic flow experience identification as a big challenge to tackle, few studies have actually been made for this purpose. Lee *et al.* [25] proposed a model to detect whether student are in flow and conducted an experiment with 55 students, using step-regression to analyse the data. How-

[1] In the proposed conceptual model document, we provided a full description of these dimensions: http://twixar.me/YyHn

Final list of found information: *(i)* Active time in the system; *(ii)* Used time to finish a step/activity; *(iii)* Proportion of correct steps/activities; *(iv)* Proportion of help requests; *(v)* Proportion of answers that were incorrect and received "error message"; *(vi)* Average response time after a feedback; *(vii)* Total unique session views; *(viii)* Number of mouse click out of buttons. Also, in our proposal document (http://twixar.me/YyHn) is possible to read a complete description about these information.

ever, the authors operationalize flow only as the perception of challenges and skills, which is actually only one of the dimensions of the flow.

Challco *et al.* [1] proposed a framework aiming to integrate the students' growth process and the Flow Theory, towards to provide support for the instructional design of learning scenarios and keep the students in the flow. Although the authors used an algorithm to identify when students are in flow, this study consists of operationalizing flow only as the perception of challenges and skills without considering other flow dimensions.

Kock [8], proposed an approach to automatic flow experience identification using an EEG. In this study, he used the equipment with 20 students during the use of an educational game in order to associate seven brain dimensions and the students flow experience. Despite being a pioneer study, the author used a short flow questionnaire (the Abbreviated Flow Questionnaire (AFQ)). Besides being an intrusive approach, with difficult access and data analysis, also it cannot be used massively with many users at the same time. Thus, as far as we know, our study is the first to propose an approach for automatic and implicit flow experience identification based on data logs from the user's interaction in educational systems.

Theory-driven Based Study

A theory-driven intervention is an intervention based on an explicit theoretical/conceptual model [31]. Our approach aimed to identify theoretical relationships between the Flow Theory dimensions and the data logs produced by students in educational systems. The study was formalized in four different steps presented in the Figure 1 and detailed below:

1. **students' data log summarizing**: In this step, we analyzed the students' data logs provided by three different large-scale educational systems in use (edX[2], FutureLearn[3], and Moodle[4]), and the results of our systematic literature review, identifying the different data logs usually provided by the educational systems. Then, 345 different types of students' data logs (*e.g.*, user id, team id, forum thread viewed, moment that a step was first visited, and moment that a step was last visited) were found;

2. **students' data log transformation into information**: In this step, based on the summarized data logs found in the first step, we extracted the information that can be generated from some log data or the combination of two or more students' data log (*e.g.*, "step first visited at" + "step last visited at" = used time to finish a step). After this step, 17 different information were identified;

3. **Match the information with Flow Theory dimensions**: In this step, we proposed a theoretical relationships between the information obtained in the previous step with each original Flow Theory dimensions (*e.g.*, which information are associated with the dimension of Challenge-skills Balance). After this step, 11 possible different relations were identified;

4. **Validation:** In this step, three researchers with expertise in data analysis and Flow Theory were invited to analyze the proposed association between the information and the flow dimensions and report in a free text if they agree or disagree with the proposed

[2] https://www.edx.org
[3] https://www.futurelearn.com
[4] https://moodle.org

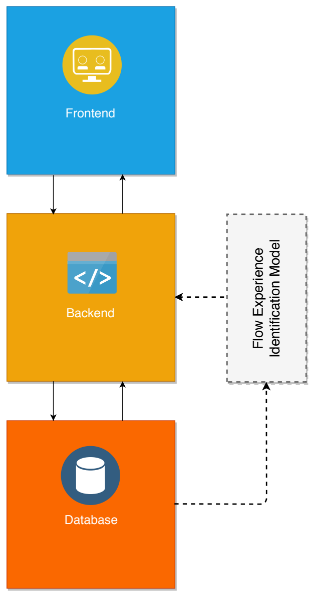

Figure 4: Model settings

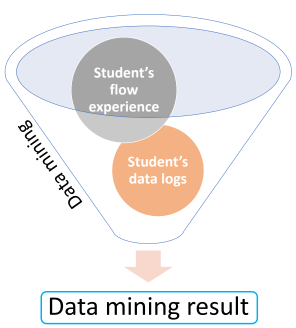

Figure 5: Data-driven approach organization

associations, as well as if any new association is suggested (see the margin note **Found information analyzed by the experts**) were found; [5]

Results, Limitations and Discussions

The invited experts analyzed the conceptual model proposed by us with 11 information related to the original nine Flow Theory dimensions (presented in the margin note **Found information analyzed by the experts**). In their analysis, no new association was advised. However, they reported the fact that some information (*e.g.*, "proportion of answers that were incorrect and received bug messages" and "proportion of slow and/or fast responses after a bug message") could represent the same thing and be represented for a general information (*e.g.*, "average response time after a feedback").

It has also been identified that some information extracted from the proposed conceptual model may be contradictory to each other and cause confusion regarding the process of data analysis (*e.g.*, "proportion of correct steps" and "proportion of answers that were incorrect and received bug messages") and could be summarized in a single information. Then, based on the analyses conducted by the experts, the proposal was refined. After the analysis, the final conceptual model was proposed with eight different information related to the nine original flow experience dimensions (the list of information after the experts validation can be seen in the margin note **Final list of found information**).

[5]In the following link, it is possible to access the complete document that describing the final relationships between the information and each flow experience dimension (after the validation), previously described in this paper: http://twixar.me/YyHn

Our intention is that our proposal can be applied in general educational systems. In order to the model operate correctly, the system needs to provide the data logs required in our approach (even if it is not some system from those used to obtain log data in the first step of our study (Moodle, edX, and FutureLearn)). Once the information can be identified, the students' flow experience may be calculated based on the metrics available in the conceptual model document (http://twixar.me/YyHn). In order to provide a real example on how the proposed approach can be used in different educational systems, we will describe a case in the following:

Suppose the use of an educational system that allows the students to log in and then start learning a particular subject through videos and/or tutorials and then answer a series of questions about a certain subject. Imagine that this system has an option for the user to ask for help at certain times (in the Figure 2 and in the Figure 3 it is possible to see the system example). Suppose also that finally, this system allows to identify enough students' data logs to obtain the information required in our approach. As exemplified in the Figure 4, the proposed approach should receive the user data logs stored in the database, calculate each flow experience dimension, and consequently the general flow experience, and then send the response to the backend, which can decide what to do with the information (*e.g.*, sending the information to the teachers enrolled in the system).

To use the proposed approach, it is important to keep collecting the required information for a certain period of time. We recommend initially at least 30 minutes of use, however, this may vary according to the system specifications where the approach is being implemented. Once in possession of this information, the values of each of the information can be calculated (based on the general students' average in the system “five number summary” (the minimum value, the first quartile, the median, the third quartile, and the maximum value of a set of numbers (data) [17]) or based on expert opinion). After the metric is calculated for each of the dimensions of the Flow, it must then be verified whether all the dimensions were considered to be positive. Only if all dimensions were considered to be positive, the results could infer that the student has achieved the flow experience in the system.

Our study has generated different limitations that should be considered in future studies. The link between information provided and flow dimensions are subjective aspects and can be analyzed differently by different people. In order to mitigate this limitation, we submitted our proposal for validation with experts and provided a real application example. Once the approach is being applied to a real system, different external aspects that cannot be observed can affect the results (*e.g.*, the user can log in to the system and then leave the site leaving the system logged in). To reduce this limitation, our approach suggests the use of “five number summary” to categorize data generated by students and identify possible “outliers”.

Although the limitations described, our approach offers an unprecedented and desired solution by the community [27, 29, 26], being able to be “plugged” into different educational systems and identify whether the students (or some specific users) achieve the flow experience in the system, or still, which dimensions could not reach. Through the proposed approach, it is possible to move towards the automatic students’ flow experience identification in educational systems, as well as to define parameters for new research in this area (*e.g.*, data mining-based approaches). Thus our approach contributes directly to the design of educational systems.

The next step of our project is to implement and validate an educational system based on the prototype presented in the Figure 2 and in the Figure 3, as well as to implement a module capable of capturing the required data logs for the proper operation of our approach. After using the system, students will be invited to respond to the flow state scale developed and validated by Jackson and Eklund [22] and Hamari and Koivisto [11]. This scale considering the nine flow experience dimensions and is the most used scale the field of educational technologies [26].

After that, the data logs produced by the students’ interactions in the system will be collected and different approaches based on data mining (*e.g.*, association and clustering [13]) will be used in order to identify relationships between the identified data logs and the students’ flow experience (now measured by scale), as summarized in the Figure 5. Finally, we aim to design a computational approach to be “plugged” in general educational system and identify the students’ flow experience, without the need for intrusive instruments.

Concluding Remarks

In this work in progress, we have proposed a theoretical approach relating user interaction based information to each of the flow experience dimensions originally proposed by Csikszentmihalyi [6]. As contribution we provided a conceptual model to implicitly identify (using only students’ data logs) the students’ flow experience in educational systems. In the next step, we aim to design a real educational system and conduct a data-driven study.

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