Improvement in educational performance through wearable-based flow predictive models

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Abstract – **Flow Theory has been used to study motivation in educational activities. However, few studies use physiological data to uncover unknown aspects of said data in any context, and isolated individuals are involved as well. In this paper, we present some of the results obtained from two control groups corresponding to two full primary education classrooms, as well as their teacher, using a quasi-experimental design. They participated in two training activities with different instructional designs and three different STEAM subjects: graphic design, video game design using Roblox Studio, and educational robotics. In this sense, the heart rate, its variability, data from accelerometers, and the educational activities carried out by the teacher have been automatically recorded for each participant at every second. To achieve this, we used smartwatches connected to Polar H10 sensors as well as our own apps. At the end of each session, everyone answered the Flow FKS and EduFlow prevalence questionnaires, and the teacher kept a class journal. Through this, we aim to understand whether the Flow Theory models derived from the FKS and EduFlow scales are valid from a physiological standpoint, as well as to develop classification and predictive models based on artificial intelligence that will allow for educational performance improvement of students in future research.**

Keywords – Flow theory, STEAM, physiology, artificial intelligence, wearables

I. INTRODUCTION

Flow Theory [1] is a psychological theory of motivation that explains why people participate willingly in certain activities. This is because participants enter a pleasurable psychological state called flow [1,2]. While there are many definitions of flow, as a phenomenon, it occurs when [3] there is balance between the difficulty of the task (challenge) and the competence of the person (skills), when there is concentration on the activity, when goals are clear, when there is immediate feedback, when the person performs the activity without apparent effort, when one feels in control, when one is absorbed in the task, and when one feels as if time is running faster than normal. In addition, as a result of flow, people improve their performance in said tasks [2,4]. However, such axioms have been nuanced [5,6]; flow is a state in constant change that is difficult to determine in practice [7], it must be understood as a multicomponent construct [8,9], and more physiology research is needed to understand it [10]. In this sense, we have found very few articles that address Flow Theory from a physiological perspective [11,12,13,14], of which none address educational settings. Additionally, available physiology research has several limitations: it often entails recruiting individual participants, its contexts prove to be artificial, the participants' mobility is very restricted, and it involves few sessions or sessions that have a short duration. Likewise, we are aware of several multicomponent theoretical models applicable to educational settings, such as EduFlow [15] and FKS [16], which, to our knowledge, have not been compared from a physiological point of view.

II. METHODOLOGY

This research has been authorised by the Ethics Committee of UNIR (ref. PI015/2022) and communicated to the Office of the Prosecutor for Minors and parental authorisation, complying with the Data Protection Act and the Declaration of Helsinki at all times. Participants were free to abandon training activities or to deny sharing their data at any time. Additionally, they did not receive prizes of any kind, and the data was made anonymous.

Furthermore, the professor was a participating researcher, so this paper was developed following the principles of action research [17] and a quasi-experimental design, with a pre-test and post-test, for two control groups and two experimental groups. In this paper, we focus on recent fieldwork with control groups. Participants belonged to two full primary education classrooms (5th and 6th grade) from a school in Granada, Spain, in conjunction with one teacher (15 individuals per group).

In order to start, 2 instructional designs in the SCORM format that follow STEAM methodology were implemented in a Moodle virtual campus. The topics were graphic design, video game design with Roblox Studio, and robotics with Arduino and were developed through 10 one-hour classroom lessons for each group during school hours in May 2022, with 2 weekly sessions. These instructional designs were developed considering an active-visual-sensing-sequential learning style according to the Felder test [18]. The topics were grouped into modules, starting with concrete examples that could be followed step by step and customised later, concluding by requesting small and simple open projects. Subsequently, SCORMS were integrated into a web application capable of monitoring the activity shown on a projector every second, its difficulty level according to Bloom's digital taxonomy [19], and the teacher's attitude when operating interactive buttons (does not explain, explains something new, or explains something previously seen), as well as immediate discretionary observations

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concerning the students' attitude. Each student received a new internet-connected laptop, an Arduino UNO robotics kit, and a mouse. They sat in the same place for each session, in rows of about 5 students parallel to the classroom projector. Both the teacher and students could move freely around the class.

Before beginning their training activities, students took the Felder-Silverman test [18] to confirm if their learning style was in line with the instructional design, as well as the SFPQ questionnaire [20], which determines the propensity to enter the Flow state. They also completed a test for existing knowledge, which would be repeated at the end of each topic, with quiz-type questions and a practical exercise.

The sessions took place at least 1 hour after entering school and before recess, with students accessing a particular classroom and resting 10 minutes before. Subsequently, each participant received a large-screen Ticwris Max smartwatch and a Polar H10 sports band, considered the gold standard [21] for the measurement of heart rate (HR) and heart rate variability (HRV). These parameters were recorded on the smartwatch's SD card at a frequency of 1Hz, along with data from the clock accelerometer. In this manner, certain authors have used HR measurements for their physiological studies of flow [11], while others considered monitoring HRV [12]. This is due to high values indicating an anxiety state, while flow would be registered at moderate levels; lower levels would indicate feelings of apathy or boredom [11]. However, it should be expected that each participant will have a different resting heart rate and that it will be necessary to determine which values are high, moderate, or low for each individual. Additionally, we developed our own app in Kotlin for the smartwatch, using the Polar H10 SDK [22] as a basis, which recorded, along with accelerometer values, if students pressed interactive buttons present on the screen that they could use at any moment to indicate they had finished the task or that they needed help. Furthermore, when sessions concluded, each participant answered the Flow FKS [16] and EduFlow [15] prevalence scales in paper format, and the teacher recorded personal impressions and incidences in a class journal.

To conclude this section, we must clarify that the EduFlow scale contains 12 items grouped into 4 dimensions (cognitive absorption, time transformation, loss of self-consciousness, and wellbeing), while the FKS scale has 13 items grouped into 3 factors (course progression, cognitive absorption, and task importance). In addition, each student was interviewed upon finishing each subject.

III. Results

It was possible to confirm, based on the Felder-Silverman test [18], that the students would adapt without relevant problems to the predominant learning style for which the instructional designs were developed. This could mean that students are comfortable starting the modules with concrete examples they can follow sequentially and then arrive at generalisations through simple projects, as we anticipated. Similarly, only 2 students demonstrated a low tendency to flow according to the SFPQ test. Additionally, the pre-test results indicate that students did not demonstrate previous knowledge of any topic worked, since they obtained zero points or did not answer anything. In contrast, the post-test results of both control groups were satisfactory, with a mean score of 7.06 and 7.98 out of 10 for 5th and 6th grade respectively. Since satisfaction levels expressed by students during the interviews averaged a rating of 9 out of 10, we can confirm that the instructional designs and the teacher's educational activities were effective and appropriate for the groups and contexts studied. As for preferences regarding the topics presented, Roblox Studio was liked more than graphic design, while artistic educational robotics projects were liked in between these two. Consequently, the topics presented could affect flow levels.

Furthermore, we found a high correlation between the EduFlow and FKS scales, despite containing different factors, since they share 73% of the explained variance. Moreover, in both cases, the scales have been shown to be reliable, with Cronbach's alpha of 0.73 and 0.85 respectively. However, the FKS values showed a clear normal distribution, whereas the EduFlow scale did not. Finally, by normalising the HR values of each 5th grade student individually and making a scatter plot with the same non-normalised values, we found a series of perfectly aligned points that show a maximum and minimum value of the HR for each participant, as well as a distinct slope (Fig. 1).

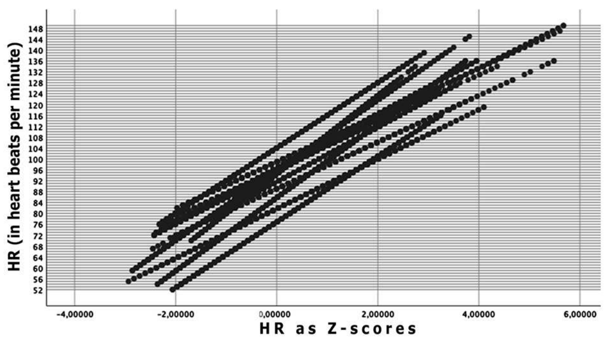

Fig. 1. The ratio between HR (in beats per minute) to HR expressed as normalised values in Z for each participant in the graphic design course. Source: self-made.

IV. Conclusions

In this ongoing research, we found that the EduFlow and FKS scales appear to measure the same construct but that the latter offers normal distributions, which would allow for more powerful statistical testing and a wider range of artificial intelligence techniques. In addition, participants react in a differential and measurable manner to the same instructional design from a physiological standpoint. Therefore, it may be feasible to confirm whether the physiological measurements obtained (HR, HRV, and accelerometer) are related to the EduFlow and FKS scales and therefore validate or not the associated flow models using classification and predictive artificial intelligence techniques. Finally, it has been shown possible to monitor full classrooms from a physiological perspective, without distracting participants from their training activities or limiting their mobility, which may be of interest to develop a new model typology for Flow Theory in educational contexts, as is our objective.

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