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Large Scale Evaluation of Learning Flow

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Abstract — **Personalized and adaptive learning is the fastest growing field in e-learning. Adaptive e-learning systems are typically well suited for real-world heterogeneous users, which exhibit different levels of motivation and knowledge. Furthermore, students learn best when they are in flow, i.e. when the level of difficulty is perfectly adjusted to their individual abilities. A personalized, adaptive, and intelligent learning environment can provide each student with this learning experience. In this paper, we present a large-scale evaluation of learning in flow within an adaptive and personalized system, the Adaptemy system. The paper presents the results of two studies: an objective study with 7,614 Irish secondary school students in math classes assessing their learning flow, and a subjective study with 80 students assessing their perceived learning experience. The results from the objective study show that 88% of the students worked within the flow channel. In the subjective study, 70% of students reported a perceived improvement in their math skills after the exercise studying with the adaptive and intelligent learning system.**

Keywords- personalization, adaptive learning, flow, learning analytics, user feedback.

I. INTRODUCTION

Docebo's e-learning market forecast for 2017-2021 [1] predicts that personalized learning is the next huge trend in the field of e-learning. Designing and developing intelligent and adaptive systems is the foundation of personalization [2]. However, while students enjoy the benefits of personalization and freedom of inquiry-based learning, they also require structure and guidance [3]. Intelligent and adaptive learning systems can facilitate each student's learning at their own pace, and perform as a one-to-one tutor [4]. Adaptive e-learning systems are typically well suited for real-world heterogeneous users [5], and can help bridge the gap between fast and slow learners [6]. Personalization in e-learning can have a positive effect on students' learning, particularly with slow learners, while enhancing the learning quality [2], [7].

This research study investigates the learning flow of 7,614 Irish secondary school students from math classes. The objective study is based on the learning analytics collected by the Adaptemy system, and the subjective study on questionnaires filled by the students. The objective study analyses the effect of adaptive content sequencing to students' learning flow. The Adaptemy system adapts the content sequence to students' performance through a dynamic difficulty adjustment algorithm. The algorithm makes use of the student ability that is constantly updated by the system, as well as of the content difficulty, to provide optimal level of challenge, keeping each student in flow.

The remaining of the paper is structured as follows. Section II gives an overview of the Adaptemy system and of learning flow. Section III presents the research methodology, while section IV presents the results analyses for the objective and subjective studies. Section V concludes the paper.

II. BACKGROUND

A. Adaptemy System

The Adaptemy system is a smart and adaptive learning environment that makes appropriate adjustments and recommendations based on student profiles, and improves the learning outcomes while creating an engaging and personalised learning experience [8]. The Adaptemy system provides personalised learning paths based on the student's previous work and progress. It follows the classical architecture of an adaptive e-learning system and consists of a Domain Model, User Model and Adaptation Engine [6]. The Domain Model organizes the educational content making a separation between curriculum and content. The curriculum includes concepts, the relationships between them, and their unique contents. The student interface resembles a familiar textbook table of contents. The adaptive learning platform supports many different types of content that can be employed in a variety of settings, with multiple question types being produced from a generic question template. Adaptemy uses curriculum-mapped content to allow users to work towards their goals using a solution that provides personalised learning journeys, that consider how the concepts relate to each other, providing maps for each topic [6].

The Adaptive Engine contains several layers of adaptation and personalization. Through this, the Adaptemy system provides immediate personalized feedback to the student, engaging content sequencing that adapts to the student's performance, adaptive assessment and scoring, learning paths recommendations and student motivation detection and learning loops. The Adaptemy system empowers the teacher with real-time classroom monitoring, the ability to set assignments and direct students towards specific goals, view student progress analytics (with details of every student's journey, their effort and progress) and to view course coverage and content analytics, receive intervention suggestions and to get reports for school admin, parents and support staff [8].

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In a previous study [8], the feasibility of integrating adaptive learning powered by the Adaptemy system in the classroom was analyzed with 62 schools from Ireland and Northern Ireland and 2691 students. The results showed that 97% of teachers believe that students enjoy using the Adaptemy system and want to use it at least once per week, while 35% would use it several times per week [8]. The greatest acknowledged advantages of Adaptemy for students included engagement through technology, immediate feedback, worked solutions, curriculum relevant content and personalised learning paths [8]. A further study with over 10,000 students using the system for more than 6 months in over 1,700 K12 math classroom sessions was carried out to analyze Adaptemy system's learning effectiveness. The students' math ability improved by 8.3% on average per concept for an average of 5 minutes and there was a statistical significant improvement across various ability ranges [6]. Moreover, a 25% problem solving speed increase was observed for the first revision, and 38% increase for the second revision [6].

B. *Flow*

The flow model aims to give the subject an optimal experience through a state of complete engagement in an activity, resulting in optimal development [9]–[12]. Flow is a psychological state where the person is so involved in the activity that other matters become irrelevant. The flow state has a positive impact on learning as learners are fully focused on the task, while feeling satisfied [10], [13]. In flow, the perceived challenges stretch existing skills, while clear goals and instant feedback are provided [9]. Flow bands show movement in and out of flow. If the level of difficulty exceeds the learner's ability, s/he will enter a state of anxiety. If the exercise is too easy, s/he will experience boredom. The flow theory is based on the challenge–skill balance, where the challenges fully engage the students' skills without overwhelming them [14]–[16].

III. METHODS

A. *Participants*

The participants were Irish secondary school students. The students (N = 7,614) used the Adaptemy system during a total of 25,945 lessons, and the data collected by the system was used in the objective study. Eighty of these students (48 females, 32 males) from 3 Irish secondary schools, have also answered a subjective questionnaire. The data collected was anonymous.

B. *Objective Methodology*

Students used the Adaptemy system both in class and at home, and the data collected by the system was analyzed to investigate the learning flow. This study investigates if the content given to the students matched the student ability to enable learning in flow.

The content used by the Adaptemy system was assigned easy, medium or hard levels, defined by subject matter experts, in the context of the Irish math curriculum. The student ability after a learning experience (ability after) is calculated by the Adaptemy system prediction algorithms that use student's previous work, results and the curriculum shape. The ability calculation on a concept was based on Item Response Theory (IRT) [17] and then propagated through Bayesian algorithms to the other concepts. The dynamic difficulty adjustment mechanism recommended the next most suitable content. As part of the study, the content difficulty was computed and validated through inverse IRT for the difficulty parameter. IRT was first proposed in psychometrics for ability assessment, and widely used in education to score subjects on abilities and attitudes. The difficulty parameter measures the difficulty of answering the item correctly. The probability of a correct response is 0.5 for any subject whose ability is equal to the value of the difficulty parameter. The student ability is represented on a continuous scale from 0 to 1. The flow bands and the flow zone analyses were based on Csikszentmihalyi's flow model [11], [12]. The model was used to categorize each learning experience in the flow channel, anxiety or boredom, based on student ability and content difficulty. The model was used to categorize student mental state of challenge in one of the following states: flow, control, relaxation, boredom, apathy, worry, anxiety, arousal.

C. *Subjective Methodology*

The students were given a questionnaire to answer after the math classes. The students were asked to rate their learning experience regarding enjoyment, confidence, math skills improvement, the relevance of the exercises to their usual math lessons, and what they thought were the main advantages of using the Adaptemy system.

IV. RESULTS

A. *Objective Study*

The difficulty level generated by the Adaptemy system is ideally related to the students' estimated ability, as 88.01% of their learning occurred within the flow channel (Fig. 1). Slower learners will gain confidence in their math skills and fast learners are appropriately challenged. 5.75% of students felt anxiety, while 6.24% experienced boredom.

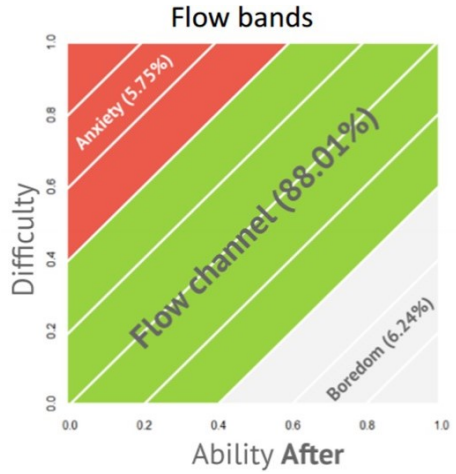

Fig. 1. Flow bands showing the percentage of learning experiences within the flow channel, anxiety and boredom.

Fig. 2 shows that 46.3% of students worked in perfect flow, while 25.71% worked in the control zone. Some students (3.67% and 1.96%, respectively) experienced relaxation and boredom. In the arousal zone (7.3% of students) the level of difficulty slightly exceeds the student's ability. The smallest percentage, 1.91%, experienced apathy, where the ability and the level of difficulty were very low. In this study, 6.82% of students experienced anxiety, while 6.36% felt worry.

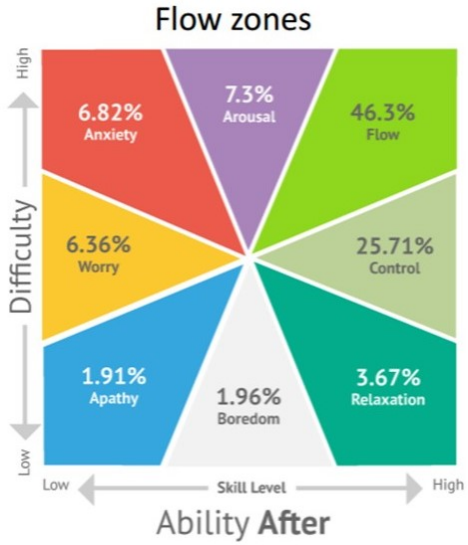

Fig. 2. Flow zones, expressed as the level of difficulty against the student's ability after the exercise.

B. *Subjective Study*

Most students (70%) reported to have felt an improvement in their math skills after the exercise, while 89% felt the exercise helped them to learn more than they had expected, a good deal or at least a little. 56% of students also reported to have an increased confidence in their skills in solving math problems, while 30% reported that the confidence remained the same. Students felt an improvement in their learning particularly through working out the solutions with hints and explanations.

60% of students thought the main advantage of the Adaptemy system was worked solutions, while more than half enjoyed learning through technology. Modern students use technology in their everyday lives, so it is only natural to utilize this in education. 42% found the personalization to be of the greatest value, as they could work on their own pace, answering questions suitable for their level. Similarly, 39% and 38% respectively, found the relevance of the exercises to the curriculum and instant, personalized feedback to be the main advantages.

V. CONCLUSIONS

In the first objective study, the clear majority of students, 88.01% learnt within the flow channel, while nearly half, 46.3% learnt in perfect flow. This indicates that the Adaptemy system matched students' abilities with a suitable level of difficulty. The results of the second study on the user experience echo the findings of the first: students felt they gained more confidence in solving math questions, and illustrated increased enjoyment, confidence and improved learning. As a conclusion, personalized and adaptive learning systems such as Adaptemy system can provide students with an optimal learning experience.

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