Development and Validation of the AI and Flow Learning Questionnaire (AIFLQ)

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Abstract

As artificial intelligence (AI) becomes more embedded in education, comprehending its influence on students' psychological involvement is crucial. Flow theory, created by Csíkszentmihályi, provides a framework for examining optimal learning experiences characterized by intense concentration and intrinsic motivation. This study introduces the AI and Flow Learning Questionnaire (AIFLQ), an enhanced and psychometrically validated iteration of Dominek's original tool. A 24-item, 5-point Likert-scale questionnaire was administered to university students (N=44) in AI-assisted classes. Exploratory factor analysis identified three dependable dimensions: Immersion, Balance, and AI Integration (Cronbach's alpha: 0.805, 0.738, 0.825). Statistical findings revealed significant gender disparities in flow, with female participants achieving higher scores, and a marked impact of educational attainment on immersion. Despite AI being associated with increased variance and diminished scores, the instrument exhibits significant potential for assessing student engagement in digital contexts. The AIFLQ functions as a comprehensive metric for forthcoming investigations on flow experiences within AI-augmented learning environments.

Keywords: Artificial Intelligence; Flow; Education; Questionnaire

1. Introduction

Today, the exponential development of Artificial Intelligence (AI) is undeniably reshaping many aspects of our daily lives. In addition to industrial and technological sectors, AI is increasingly present in everyday life, from smartphones to online communication platforms to education. While the use of AI can bring significant benefits, it is important to consider the potential negative impacts it may have on human cognition, communication and social interactions in the long term. In parallel with the rise of AI, it is crucial to address the question of what human competencies will be essential in the 21st century. Human competences are understood as the integrated knowledge, skills, attitudes and values that enable individuals to function effectively in different social, economic and cultural contexts (Rychen – Salganik, 2003). They include not only specific professional knowledge but also a wide range of cognitive, social and emotional skills.

In the literature, competences are often grouped into three basic categories (Rychen – Salganik, 2003; European Parliament and Council, 2006; Ferrari, 2013): Cognitive competences (e.g., complex problem solving, critical thinking, creativity, analytical skills);

Social and emotional competences (essential for successful interactions and conflict management); and Technological and digital competences (including confident use of IT tools, digital literacy, and skills for interacting with AI). The OECD (OECD, 2019) and the World Economic Forum (World Economic Forum, 2020) predict that as AI and automation become more widespread, some human competencies will become more valuable. While machines can effectively automate repetitive tasks, human creativity, intuition, moral judgement, and social intelligence are difficult to adequately replicate. Particularly important skills for the future are considered to be creativity, emotional and social intelligence, ethical reasoning and responsibility, and learning capacity.

As artificial intelligence becomes more prevalent in education, it is crucial to understand its impact on students' psychological engagement. Csíkszentmihályi's flow theory provides a framework for examining optimal learning experiences characterised by intense concentration and intrinsic motivation. This study introduces the AI and Flow Learning Questionnaire (AIFLQ), an improved, psychometrically validated version of Dominek's original tool (Dominek, 2023). The AIFLQ serves as a comprehensive metric for future research on flow experiences in AI-enhanced learning environments.

This study's distinctive contribution lies in its conceptual and empirical integration of artificial intelligence as an innovative third factor in the flow experience. By explicitly incorporating AI integration into the measurement model, the AIFLQ broadens the scope of traditional flow assessment frameworks, offering new insights into how intelligent technologies influence learners' engagement and motivation. This conceptual advancement reflects the evolving nature of digital learning environments and establishes the AIFLQ as a valuable instrument for exploring modern educational experiences.

However, the generalisability of the findings is limited by the relatively small sample size used in the validation process. Future research should therefore replicate and extend these findings through large-scale, longitudinal studies, in order to better understand the stability and applicability of the instrument across diverse educational settings and populations. This would strengthen the psychometric robustness of the AIFLQ and provide deeper insights into the sustained impact of AI integration on students’ flow states.

2. Literature Review

The flow theory, developed by Mihály Csíkszentmihályi (1975, 1990), describes a mental state of complete immersion, concentration and enjoyment while performing an activity. Flow occurs when the level of challenge is just right for the person's abilities; if the challenge is too high, anxiety may develop, while if it is too low, boredom may occur (Csíkszentmihályi, 1998).

AI-based educational applications play a role in facilitating the flow experience (Hwang et al., 2012). For example, AI-based systems can identify learners' individual learning styles, pace, strengths and weaknesses. Based on this, the system can provide personalised learning paths and tasks that are optimally challenging for the learner, thus facilitating the flow experience. The immediate and adaptive feedback provided by the system can help learners monitor their progress and maintain motivation, which is also a factor related to flow. The clear goals and continuous, targeted feedback that intelligent tutoring systems provide are key elements of the flow experience (Csíkszentmihályi, 1990). AI-generated learning analytics can help learners see their own progress. Perceiving progress and experiencing growth in competence can positively influence motivation and contribute to the experience of flow (Bandura, 1977).

While AI has significant potential to facilitate the Flow experience in educational development, it is important to address the challenges and ethical issues associated with its implementation that can negatively impact the Flow experience. These include the collection and use of student data, which raises serious privacy and security concerns. Loss of trust and control can reduce student engagement and negatively impact the flow experience (Selwyn, 2021). Unfair or discriminatory assessment or learning opportunities can lead to frustration and loss of motivation due to biased algorithms, hindering the development of the flow experience. If AI takes over too much of the educator's role in personal interaction and learner support, it can reduce the sense of connectedness and richness of the learning environment, which can negatively impact the flow experience. Unequal access to AI-based tools may prevent some learners from experiencing the benefits of personalised learning and the potential flow experience, increasing frustration and feelings of exclusion. In order to measure AI and flow learning outcomes, the author created an improved version of the Dominek Learning Flow Questionnaire (Dominek, 2023), the AI and Flow Questionnaire (AIFLQ), which will be presented in detail later in this paper.

3. Research objective

The primary research objective is to explore students' flow experience within Artificial Intelligence (AI)-supported learning environments and to investigate factors influencing this experience, specifically using the AI and Flow Learning Questionnaire (AIFLQ). Particular emphasis is placed on examining gender, educational attainment, and age differences among university students regarding the dimensions of the flow experience (Immersion, Balance, AI Factor) and the total flow score. The study aims to utilize the AIFLQ as a comprehensive metric for this investigation.

3.1. Research questions

1RQ: What are the dimensions of the flow experience in AI-supported learning environments as measured by the AIFLQ?

2RQ: Are there significant gender differences in the flow experience (Immersion, Balance, AI Factor, Total score) among students participating in AI-supported learning environments?

3RQ: Does educational attainment (secondary vs. higher education) influence the flow experience (Immersion, Balance, AI Factor, Total score) among students in AI-supported learning environments?

4RQ: Are there significant differences in the flow experience (Immersion, Balance, AI Factor, Total score) among students of different age groups (18-25 years, 26-33 years, over 34 years) in AI-supported learning environments?

5RQ: How do students perceive the role of artificial intelligence in their flow experience during learning tasks?

4. Methodology

In developing the AI and Flow Learning Questionnaire (AIFLQ), we reviewed the AI and Flow literature, examined previously used measurement instruments and their associated item banks (Webster - Trevino - Ryna 1993; Ghani - Deshpande 1994; Novak - Hoffmann 1997; Oláh 1999, 2005; Chen 2006; Magyaródi 2013, Dominek 2023). After reviewing the item banks and eliminating duplicates, the AI and Flow Learning Questionnaire was created, resulting in an improved version of Dominek's Learning Flow Questionnaire, a 24-item, five-point Likert-scale measure (1: very characteristic; 2: characteristic; 3: neutral; 4: not characteristic; 5: not at all characteristic).

In order to test the instrument, an empirical study was carried out in university classes for students of the Ludovika University of Public Service (hereafter: LUPS), in which a total of 44 students completed the questionnaire. An exploratory factor analysis was carried out for item selection, descriptive factor statistics and reliability, with the aim of checking the separation of the scales. The items were grouped into three factors to obtain a 24-item, three-factor (immersion, balance and AI factor) model.

The „immersion” factor captures the experience of the lesson, focusing on engagement, the quality of the experience and accompanying phenomena such as changes in time perception and disregard for the environment. Csíkszentmihályi (1997) described flow as deep involvement that is enjoyable in itself and involves maximum concentration on the task and its solution. Involvement and becoming one with the task depends on the individual's attitude towards the activity (Diaz, 2011) and whether he or she has the necessary developmental potential to be activated.

The „balance” factor relates to the task and activity and its content covers the areas of challenge-skill balance, control and clear goals in classroom tasks. In their early Experience Sampling Method studies, Csíkszentmihályi, Rathunde and Whalen (2010) defined flow experience as the optimal ratio of perceived challenge to perceived skill (high and balanced). Kawabata and Mallett's (2011) research also showed that individuals are more likely to enter a state of flow when there is a balance between challenge and ability.

The „AI” factor refers to the experience and balance of challenge and skill in the AI tasks given in class. This factor represents the integration of the two factors mentioned above (immersion and balance) in the context of AI tasks. Four questions explore the immersion factor and four questions explore the balance factor in relation to AI tasks. This factor therefore covers both the instructional experience provided by AI and the areas of challenge-skills required to continue the AI activity. An appropriate level of digital literacy is essential for the successful completion of classroom tasks and its development is the responsibility of the teacher. This is supported by the study by Zawacki-Richter et al. (2019), which, in analysing research on AI, highlights the importance of developing digital competence in both teachers and students.

The questionnaire was used to measure mixed-methods communicative lessons supplemented with different AI programs (N=44), and then repeated exploratory factor analysis was used to test the structure of the questionnaire. SPSS statistical software was used to analyse the data. Based on the above, exploratory factor analyses were performed on the questionnaire in order to develop a reliable measure of AI and flow in learning environments. The questionnaire is an extended version of the previous Dominek Learning Flow Questionnaire with 16 items and 2 factors, which now includes a third factor to measure AI.

5. Results

This paper presents descriptive statistics and reliability indicators for the 24-item scales of the AI and Flow Learning Questionnaire. The results indicate that the reliability indicators of the three factors were psychometrically adequate (“Balance” scale: Cronbach's Alpha = 0.738; “Immersion” scale: Cronbach's alpha = 0.805; “AI” scale: Cronbach's alpha = 0.825) (see Tables 1, 2 and 3).

Table 1. Reliability statistics for Balance factor
Reliability Statistics

Cronbach’s Alpha	Cronbach’s Alpha Based on standardized Items	N of Items
0.738	0.742	8

Table 2. Reliability statistics for Immersion factor
Reliability Statistics

Cronbach’s Alpha	Cronbach’s Alpha Based on standardized Items	N of Items
0.805	0.829	8

Table 3. Reliability statistics for AI factor
Reliability Statistics

Cronbach’s Alpha	Cronbach’s Alpha Based on standardized Items	N of Items
0.825	0.820	8

The necessary descriptive statistics have been presented for the three factors and for the overall results. These show that sample respondents scored on average higher on the deepening factor than on the balance factor, but lowest on the AI factor. However, the standard deviation scores for responses to the AI factor resulted in higher standard deviation scores than for the other two factors. In addition, respondents scored an overall average of 92.795 points (see Table 4).

Table 4. Descriptive Statistics for factors and total score

	Immersion factor	Balance factor	AI factor	Total
N Valid	44	44	44	44
Mean	32.5909	32.909	27.2955	92.7955
Std. Deviation	5.23991	4.37657	6.99362	9.57851

The reliability tests carried out showed that the questions met the validation value, so no further testing was deemed necessary. The factor analyses of the questionnaire are presented in Tables 5, 6 and 7.

Table 5. Descriptive statistics of immersion factor
Item statistics

	Mean	Std. Deviation	N
1. I regularly checked my watch to see how much time was left in the lesson.	4.27	0.785	44
2. I became aware of the non-lesson related things going on around me during the lesson.	3.59	1.300	44
3. I also remembered my personal or other problems during the lesson.	4.20	0.978	44
4. I was very interested in the lesson.	4.48	0.698	44
6. I was bored in class.	4.57	0.789	44
12. I was so absorbed in my work that I didn't notice that half the lesson was over.	3.45	1.302	44
13. I was completely relaxed during the lessons.	3.37	1.208	44
15. My attention was fully engaged in the task(s) assigned.	4.30	0.795	44

Table 6. Descriptive statistics of balance factor
Item statistics

	Mean	Std. Deviation	N
5. I was easily distracted from the lesson.	4.16	1.055	44
7. Sometimes, after completing a big task, I felt joy in the classroom.	4.23	0.743	44
8. It took effort to complete the lesson task(s).	3.27	1.149	44
9. I felt I could meet the requirements of the class.	4.20	0.823	44
10. I was motivated enough to complete the task(s) in class.	4.16	1.010	44
11. I didn't understand the exercises given in class.	4.09	0.858	44
14. The task(s) felt very difficult.	4.45	0.975	44
16. I was aware of the lesson task(s).	4.34	0.645	44

Table 7. Descriptive statistics of AI factor
Item statistics

	Mean	Std. Deviation	N
17. I did not find the AI tasks in the classroom challenging enough.	3.66	1.219	44
18. The AI made it easier for me to concentrate on getting things done.	2.84	1.238	44
19. The use of AI tools made my learning experience more enjoyable.	3.41	1.335	44
20. During the AI application, time passed more slowly and I was less able to immerse myself in the tasks.	3.66	1.430	44
21. AI applications helped me keep my attention in the classroom.	2.77	1.327	44
22. With the help of the AI, I did better on the tasks.	3.00	1.364	44
23. I found it difficult to use the AI during the lessons to complete the tasks.	3.77	1.273	44 44
24. I felt uncomfortable using AI applications.	4.18	1.225	44

To research potential gender-based differences in the experience of flow, a series of Mann–Whitney U tests were conducted using gender (male vs. female) as the independent variable and four flow-related factors – Immersion, Balance, AI, and Total flow score – as dependent variables (see Table 8). These factors represent core components of the flow state as measured by the flow questionnaire. Across all factors, female participants consistently demonstrated higher mean ranks compared to male participants (Figures 1–3), suggesting a more intense or positive flow experience overall.

The differences were statistically significant for Immersion, Balance, and the Total score. The significantly higher Immersion scores among women indicate that they reported a deeper involvement and absorption in the activity. In the Balance factor – which reflects the perceived equilibrium between challenges and skills – women also scored significantly higher, suggesting a greater subjective alignment between task demands and personal competence. The Total flow score, representing a comprehensive measure of the flow state, was likewise significantly elevated for female participants, pointing to a generally richer and more cohesive flow experience.

In contrast, while women again showed higher mean ranks in the AI factor, the difference did not reach statistical significance. This subscale may tap into the participant's perception of system intelligence or adaptability, and its non-significance could imply that both genders evaluated this aspect similarly, or that the AI component was less central in eliciting flow.

Overall, the results indicate a gender-related pattern in the intensity of flow experiences, with women reporting stronger engagement in key dimensions of the flow state. These findings raise important questions about how different user characteristics, including gender, shape subjective experiences during digital tasks. The non-significant difference in the AI-related subdimension further suggests that technological aspects may be perceived more uniformly, warranting additional research on how AI interfaces interact with individual differences in generating flow.

Table 8. Mann-Whitney U test results by gender
Hypothesis test summary

Null hypothesis	Test	Sig.[a,b]	Decision
1. The distribution of Immersion factor is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	<0.001	Reject the null hypothesis.
2. The distribution of Balance factor is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	0.019	Reject the null hypothesis.
3. The distribution of AI factor is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	0.558	Retain the null hypothesis.
4. The distribution of total points is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	<0.001	Reject the null hypothesis.

a. The significance level is 0.050.
b. Asymptotic significance is displayed.

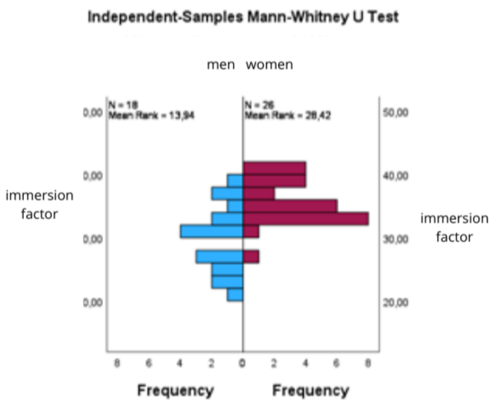

Fig. 1. Distribution of Immersion Factor Scores by Gender

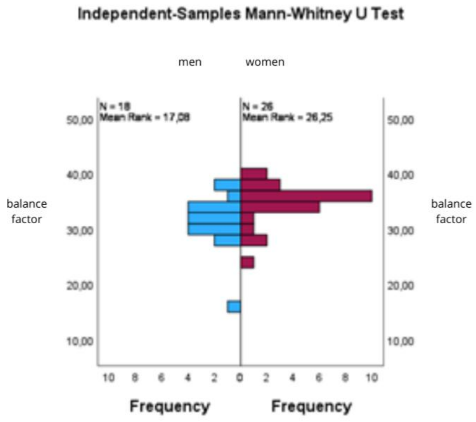

Fig. 2. Distribution of Balance Factor Scores by Gender

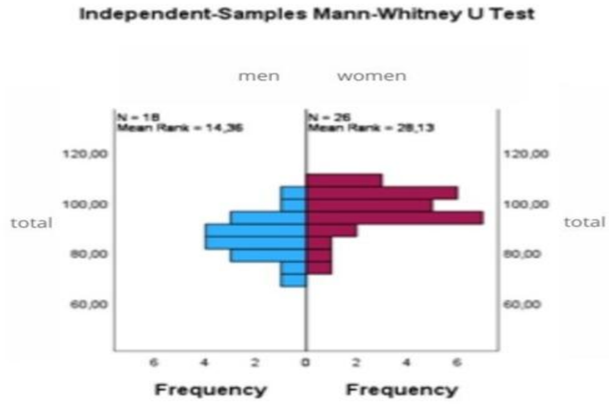

Fig. 3. Distribution of Total Flow Score by Gender

To explore the influence of educational background on the experience of flow, Mann–Whitney U tests were conducted comparing individuals with higher education to those with secondary education across the four flow-related factors: Immersion, Balance, AI, and Total flow score (see Table 9).

The results indicate a statistically significant difference only for the Immersion factor. As illustrated in Figure 4, participants with higher education achieved significantly higher mean ranks in this dimension, suggesting that they experienced deeper psychological engagement and absorption during the task. This finding implies that educational attainment may enhance one's ability to fully concentrate and lose oneself in an activity – an essential feature of the flow state.

Table 9. Mann-Whitney U test results by Educational Attainment
Hypothesis test summary

Null hypothesis	Test	Sig.[a,b]	Decision
1. The distribution of Immersion factor is the same across categories of Education level.	Independent-Samples Mann-Whitney U Test	0.043	Reject the null hypothesis.
2. The distribution of Balance factor is the same across categories of Education level.	Independent-Samples Mann-Whitney U Test	0.600	Retain the null hypothesis.
3. The distribution of AI factor is the same across categories of Education level.	Independent-Samples Mann-Whitney U Test	0.355	Retain the null hypothesis.
4. The distribution of Total score is the same across categories of Education level.	Independent-Samples Mann-Whitney U Test	0.083	Retain the null hypothesis.

a. The significance level is 0.050.
b. Asymptotic significance is displayed.

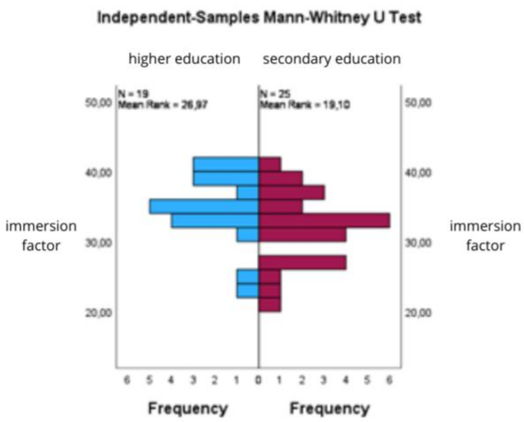

Fig. 4. Distribution of Immersion Factor Scores by Educational Attainment

To assess whether age influences the experience of flow, participants were categorized into three age groups: 18–25 years, 26–33 years, and 34 years and above. These groups were compared across the four flow-related factors (Immersion, Balance, AI, and Total flow score) using Kruskal–Wallis H tests (see Table 10).

The analysis revealed no statistically significant differences between the age groups for any of the flow dimensions. Although minor variations in mean ranks were observed across the groups, none of these differences reached the threshold for significance. This suggests that the subjective experience of flow awas relatively stable across the age spectrum represented in the sample.

The lack of significant age effects may indicate that the capacity to experience flow is not strongly tied to chronological age, at least within the adult population examined. It is possible that the task and context provided a sufficiently universal structure for engagement, minimizing the influence of age-related factors such as cognitive processing speed, technological familiarity, or life experience. Alternatively, it may reflect that age-related differences are overshadowed by other variables, such as individual motivation, personality traits, or prior exposure to similar digital environments.

Overall, these results suggest that, unlike gender and educational attainment (in the case of Immersion), age does not appear to be a distinguishing factor in how users experience flow in this context.

Table 10. Kruskal-Wallis H Test Results by Age Group
Hypothesis test summary

Null hypothesis	Test	Sig.^{a,b}	Decision
1. The distribution of Immersion factor is the same across categories of Age encoded.	Independent-Samples Kruskal-Wallis Test	,073	Retain the null hypothesis.
2. The distribution of Balance factor is the same across categories of Age encoded.	Independent-Samples Kruskal-Wallis Test	,957	Retain the null hypothesis.
3. The distribution of AI factor is the same across categories of Age encoded.	Independent-Samples Kruskal-Wallis Test	,287	Retain the null hypothesis.
4. The distribution of Total is the same across categories of Age encoded.	Independent-Samples Kruskal-Wallis Test	,828	Retain the null hypothesis.

a. The significance level is 0.050.

b. Asymptotic significance is displayed.

6. Discussion

The primary aim of this research was to explore the flow experience of students in an artificial intelligence (AI)-assisted learning environment and to investigate the factors influencing the flow experience using the Artificial Intelligence and Flow-Learning Questionnaire (AIFLQ). Particular emphasis was placed on investigating possible differences in demographic characteristics - gender, education and age - on the dimensions of flow experience and overall flow score. To this end, the AIFLQ questionnaire was developed, validated and then administered to university students. The results of the study provide rich insights into how students experience AI-enhanced learning and how this relates to achieving an optimal experience, the flow state.

RQ1: What are the dimensions of the flow experience in an AI-enhanced learning environment as measured by the AIFLQ?

One of the main outcomes of this research is the development and validation of the AIFLQ questionnaire, which identified three reliable dimensions (factors) to measure the flow experience in an AI-enhanced learning environment. These dimensions were separated based on exploratory factor analysis:

Immersion factor: This dimension measures intense concentration and total immersion in the activity. It includes items relating to the exclusion of distractions, loss of sense of time and interest in the task.

Balance factor: This factor reflects the perceived balance between challenge and ability, and the sense of competence required to complete tasks successfully. Items focus on task difficulty, sense of accomplishment and motivation.

AI Integration Factor: This dimension specifically measures the role of AI in the learning process and the students' experience of it. Items relate to AI-related challenge, concentration, performance, enjoyment and ease of use.

The reliability of these dimensions is supported by corresponding Cronbach's alpha values (Immersion: 0.805; Balance: 0.738; AI Factor: 0.825), indicating that the questionnaire consistently measures these constructs. The results indicate that the flow experience in AI-supported environments is also multi-component and that it is particularly important to examine the role of AI as a separate dimension.

RQ2: Are there significant gender differences in flow experience (immersion, balance, MI factor, total score) between students in AI-supported learning environments?

Statistical analyses (Mann-Whitney U-tests) revealed significant gender differences in flow experience. Female participants scored significantly higher than male participants on the dimensions of Immersion (Figure 1), Balance (Figure 2) and Total Flow Score (Figure 3). This means that women in this sample reported greater psychological engagement and depth (higher Deepening scores). They also had a better sense of balance between the challenge of the tasks and their own abilities, reflected in a higher score on the Balance dimension. The overall results also show that women generally had a richer and more cohesive flow experience in AI-supported classes. It is important to note that there were no significant gender differences on the AI factor. Although the average score for women was higher here, this difference did not reach the level of statistical significance. This may indicate that both genders perceived or valued the AI component of the learning process similarly, or that the role of AI was less central to the flow differences between the genders. The results raise the question of how user characteristics, such as gender, influence subjective experiences in digital environments.

RQ3: Does educational level (secondary vs. higher education) influence the flow experience (Immersion, Balance, AI factor, Total score) of students in AI-enhanced learning environments?

Based on Mann-Whitney U tests examining the effect of educational attainment, a significant difference was found only in the Immersion factor between participants with higher and secondary education (Figure 4). Participants with higher education had significantly higher mean scores on the Immersion dimension. This finding may suggest that higher levels of education may increase the ability of students to become more deeply immersed and focused during an activity, a key characteristic of the flow state. There are no significant differences in Balance, AI Factor or Total Flow scores by level of education in this sample.

RQ4: Is there a significant difference in flow experience (Immersion, Balance, AI Factor, Total score) between students of different ages (18-25 years, 26-33 years, 34 years and above) in AI-supported learning environments?

No statistically significant differences were found in any of the dimensions of flow experience (immersion, balance, AI factor) or in the total flow score, based on Kruskal-Wallis H-tests examining differences between age groups (18-25 years, 26-33 years, 34 years and over). This result suggests that the subjective experience of flow was relatively stable across the adult age groups studied in this specific context. Age-related factors such as cognitive processing speed, technological ability or life experience did not show a significant influence on flow in this study. It is possible that the nature of the task or the structure of the learning environment generally supported engagement, or that other individual-level variables (e.g. motivation, personality traits) had a stronger effect than age.

RQ5: How do students evaluate the role of AI in their experience of flow during their learning tasks? The assessment of the role of students' AI is most evident in the AI factor scores and related statistics. Overall, in terms of mean scores, students scored lowest on the AI factor (mean 27.2955) compared to Immersion (32.5909) and Balance (32.9091). In contrast, the standard deviation of scores on the AI factor was the highest (6.99362) compared to the other two factors. The abstract also mentions that AI was associated with increased variance and decreased scores.

These results suggest that although AI was present in the learning environment, students on average perceived it as less directly supportive of the flow experience than general immersion in the learning task or the balance of challenge and ease. And the higher variance suggests that students' perceptions of AI and its impact on flow were more varied than other dimensions of flow.

The mean scores of the items specific to the AI factor provide further detail. Some items dealing with negative or challenging aspects of AI (e.g. “I did not find the AI tasks challenging enough” - mean 3.66; “I found the time spent using AI...” - mean 3.66; "I found it difficult to use the AI...” - mean 3.77; “I felt uncomfortable using the AI applications” - mean 4.18), showing relatively high mean scores on a 5-point Likert scale, where 1 means “very typical” and 5 means “not typical at all” (some items were reverse scored). In contrast, items measuring the positive contribution of AI (e.g. “AI applications helped me keep my attention” - mean 2.77; “AI helped me perform better on tasks" - mean 3.00; “Using AI made it easier to concentrate" - mean 2.84; “Using AI tools made the learning experience more enjoyable" - mean 3.41) show lower means, closer to the "neutral" (3) or “typical” (2) categories. This pattern suggests that some students experienced challenges or discomfort when using AI, which may reduce flow, while the perceived benefits of AI (help with attention, performance, concentration, enjoyment) were less likely to be considered typical or salient to the flow experience, at least on average.

The final part of the research confirms this interpretation, highlighting that while AI has the potential to support flow (personalised challenges, clear goals, immediate feedback), its practical implementation raises a number of challenges and ethical issues. Privacy, loss of trust, algorithmic bias, lack of human interaction, loss of autonomy or unequal access can all have a negative impact on flow. The results obtained (low average AI factor, high variance) are consistent with these potential negative effects and the complexity of AI integration.

7. Conclusions

The research successfully demonstrated the AIFLQ questionnaire as a tool for measuring flow experiences in an AI-supported learning environment. It was found that flow in this context can be divided into three main dimensions: immersion, balance and the AI-specific factor. The results suggest that demographic factors such as gender and educational level significantly influence flow experience, particularly in the immersion dimension. Women tended to have a deeper flow experience, while those with higher levels of education tended to be more immersed in the learning tasks. Age did not show a significant relationship with flow in this sample. The assessment of the role of AI in flow shows a more complex picture. The lower mean score and higher variance of the AI factor suggest that AI was perceived less consistently and positively as a facilitator of flow than other aspects of learning. Students' experiences were varied and the item level results suggest that difficulties, discomfort or lack of challenge associated with using AI may have a negative impact on flow.

All this supports the conclusion of the sources that AI can be a promising tool to promote flow, but only if it is integrated in a pedagogically conscious and ethical way. Addressing the human factors (e.g. teacher support, social interaction) and the challenges posed by AI (privacy, bias, autonomy) is essential to achieve an optimal learning experience and flow in AI-enhanced environments. AIFLQ could be a useful tool to further explore these dynamics in future research.

8. Limitations and Future Work

Artificial intelligence offers great potential for enhancing learners' flow experiences in education. The ability of AI-based systems to generate personalised challenges tailored to individual abilities and developmental pace is key to achieving a state of flow (Csikszentmihalyi, 1990). It is also important to formulate clear goals and structured tasks, and AI can assist with this by clarifying learning pathways and scaffolding cognitive demands to maintain learner focus. Furthermore, the immediate and relevant feedback offered by AI-powered tutoring systems and assessment tools allows for the continuous monitoring and correction of progress, which are dynamic components of the flow process (Hwang et al., 2012).

However, the implementation of AI in education also raises critical ethical and social concerns. Poorly designed or excessive AI integration can hinder rather than enhance student immersion and motivation. For example, algorithmic biases in personalisation systems can lead to inequitable learning experiences, and overly directive AI systems can undermine learners' autonomy, which is essential for sustaining intrinsic motivation and flow (Deci & Ryan, 2000). Furthermore, AI alone cannot replace the socio-emotional support and human connection vital to student well-being (Selwyn, 2021). Excessive screen time and reduced face-to-face interaction may diminish the positive emotional states typically associated with flow. This highlights the invaluable role of educators (Dominek, 2022), who must integrate AI tools in a pedagogical and ethical manner to support learners' individual needs, stimulate critical thinking and creativity, and avoid merely automating learning tasks. Teachers must preserve human relationships, foster social-emotional development, and cultivate an environment in which flow can naturally emerge.

Beyond its theoretical significance, the AI and Flow Learning Questionnaire (AIFLQ) has notable practical applications in educational settings. As a validated tool that captures the dynamic interplay between AI integration and flow experiences, the AIFLQ can inform evidence-based instructional design. It enables educators and curriculum developers to identify conditions that foster optimal engagement, contributing to learning environments characterised by sustained attention, intrinsic motivation and deep cognitive involvement.

In teacher education, the AIFLQ can be used for diagnosis and reflection. It can help pre-service teachers to explore how technological components influence learner engagement, and guide them in developing pedagogical strategies that leverage AI tools effectively to support diverse learning needs. Professional development programmes based on AIFLQ findings can enhance teachers' ability to create balanced, learner-centred approaches in AI-enhanced environments.

Furthermore, the AIFLQ shows promise in advancing adaptive learning systems. By embedding flow-sensitive diagnostics into AI-driven platforms, these systems can respond dynamically to learners' changing needs, adjusting content difficulty, pacing or instructional modality in real time to sustain flow. Thus, the AIFLQ supports the evaluation of learning experiences and enhances the personalisation and overall effectiveness of AI-mediated education in multiple areas.

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Appendix A

AI and Flow Learning Questionnaire

For each of the statements below, think about the tasks you will be doing in class. Using the scale, indicate how often the statement occurs to you. Please mark one appropriate response for each item listed:

1 - Not at all often - 5- Very often

1. I regularly checked the clock to see how much time was left in the lesson. * 1 2 3 4 5

2. I was aware of things going on around me during the lesson. * 1 2 3 4 5

3. I was also aware of personal or other problems during the lesson. * 1 2 3 4 5

4. I was very interested in the lesson. 1 2 3 4 5

5. I was easily distracted from the lesson. * 1 2 3 4 5

6. I was bored during the lesson. * 1 2 3 4 5

7. I sometimes felt happy in class after doing a big task. 1 2 3 4 5

8. It took effort to do the task(s) in class. * 1 2 3 4 5

9. I felt I could meet the requirements of the lesson. 1 2 3 4 5

10. I felt motivated to complete the task(s) in the lesson. 1 2 3 4 5

11. I did not understand the tasks given in class. * 1 2 3 4 5

12. I was so absorbed in my work that I didn't notice that half the lesson was over. 1 2 3 4 5

13. I was completely relaxed during the lesson. 1 2 3 4 5

14. I found the task(s) very difficult. * 1 2 3 4 5

15. My attention was fully focused on the task(s). 1 2 3 4 5

16. I was aware of the lesson task(s). 1 2 3 4 5

17. I did not find the AI tasks in class challenging enough. 1 2 3 4 5

18. The use of AI made it easier for me to concentrate on the task(s). 1 2 3 4 5

19. The use of AI tools made my learning experience more enjoyable. 1 2 3 4 5

20. Time passed more slowly and I was less able to concentrate on tasks when using AI. 1 2 3 4 5

21. AI applications helped me keep my attention in class.1 2 3 4 5

22. AI helped me perform better on task(s). 1 2 3 4 5

23. I had difficulty using AI in class to complete class assignments* 1 2 3 4 5

24. I felt uncomfortable using AI applications* 1 2 3 4 5

* reverse position