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Articles

Augmented Reality and intrinsic motivation: a preventive approach to dropout in upper secondary school

Realtà aumentata e motivazione intrinseca: approccio preventivo al drop-out nella scuola secondaria di secondo grado

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Abstract

The phenomenon of school dropout represents a significant challenge for educational systems. Research showes that student motivation is a key predictor of school persistence, influencing the quality and continuity of learning processes (Froiland et al., 2016). In this context, Augmented Reality (AR) has emerged as an innovative tool capable of increasing student engagement and motivation (Garzón et al., 2021; Lembo et al., 2023). This paper presents an experimental study conducted with upper secondary school students, aimed at investigating the role of AR in supporting intrinsic motivation. The intervention, implemented through the Merge Cube, revealed significant differences in interest, effort, and perceived pressure, confirming the potential of AR as an innovative teaching strategy and as a preventive approach to school dropout.

Keywords: merge cube; innovative teaching; engagement.

Sintesi

Il fenomeno della dispersione scolastica rappresenta una sfida significativa per i sistemi educativi. La ricerca evidenzia come la motivazione degli studenti sia un predittore fondamentale della persistenza scolastica, influenzando la qualità e la continuità dei processi di apprendimento (Froiland et al., 2016). In quest'ottica, la Realtà Aumentata (AR) si è affermata come uno strumento innovativo, capace di aumentare il coinvolgimento e la motivazione degli studenti (Garzon et al., 2021; Lembo et al., 2023). La presente ricerca sperimentale, condotta con studenti della scuola secondaria di secondo grado, ha indagato il ruolo della Realtà Aumentata nel sostenere la motivazione intrinseca. Tale intervento, tramite Merge Cube, ha evidenziato differenze significative nelle dimensioni di interesse, impegno e pressione percepita, confermando il potenziale dell'AR come strategia didattica innovativa e come approccio preventivo al drop-out scolastico.

Parole chiave: merge cube; didattica innovativa; coinvolgimento.

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[1] The contribution represents the result of a collaborative effort among the authors. Specifically, Luna Lembo is author of § 3, 4, 6 & 7; Elisabetta Tombolini is author of § 1, 2 & 5; Stefania Morsanuto supervised the research project.

1. Introduction

In the current educational landscape, characterized by rapid social, cultural, and technological changes, the topic of learning motivation and the factors that influence it plays a central role in pedagogical reflection and empirical research. International literature agrees in recognizing that motivation is not a mere accessory element of the educational process but rather a structural component capable of profoundly influencing the quality, continuity, and effectiveness of learning experiences (Keklik et al., 2012; Froiland et al., 2016). Motivation is closely linked to students' commitment and willingness to actively participate in educational activities, determining the level of attention and effort invested in their academic journey (Alhadi et al., 2017). Several studies have shown that student motivation is influenced by multiple factors, including emotional, cognitive, and social aspects, which interact continuously and dynamically (Kim et al., 2013; Wijaya et al., 2017). Furthermore, the quality of learning is closely correlated with motivation and with students' ability to connect new information to prior knowledge, promoting meaningful and lasting learning (Bonaiuti, 2013). Therefore, fostering motivation in students not only improves the effectiveness of the educational process but also contributes to the development of transversal skills essential for facing the challenges of the contemporary world. In particular, the Self-Determination Theory (SDT), developed by Deci and Ryan (1985, 2000), provides a solid theoretical framework for understanding the different levels of autonomy and regulatory forms that guide motivated behavior, distinguishing between intrinsic motivation, extrinsic motivation, and amotivation along a continuum reflecting perceived self-determination. Numerous empirical studies confirm that autonomous motivation — based on personal interests and the identification of underlying values in the activity — is a protective factor against school dropout and supports commitment, resilience, and persistence in academic paths (Ratelle et al., 2007; Renaud-Dubé et al., 2015; Fan et al., 2014). Conversely, high levels of controlled motivation, characterized by external or introjected pressures, are associated with superficial learning behaviors and an increased risk of dropout (Meyers et al., 2013; Alivernini et al., 2011; Antúnez et al., 2017). Within this theoretical framework, a second dimension of growing interest in educational research is the role of immersive technologies, particularly Augmented Reality (AR), in teaching and learning processes (Lembo et al., 2023; Cipollone et al., 2023). AR, defined as a technology that allows the superimposition of virtual elements on the real environment in an interactive, three-dimensional format (Wu et al., 2013), represents a powerful tool for enriching educational experiences by offering opportunities for experiential and contextualized learning (Lembo et al., 2023). AR applications have demonstrated the ability to break down traditional barriers between theory and practice, stimulating curiosity, autonomous exploration, and critical thinking (Garzon et al., 2021). Moreover, AR emerges as an adaptive resource, capable of responding to different cognitive and learning styles and promoting educational inclusion through the modulation of sensory stimuli according to students' specific needs (Koumpouros et al., 2024). Nonetheless, despite the potential of such tools, research highlights how traditional teaching strategies often fail to sustain student motivation, leading to disengagement and low participation (Hamari et al., 2014; Sun & Hsieh, 2018). In this sense, the challenge for contemporary pedagogy is to foster dynamic and personalized learning environments that stimulate not only cognitive engagement but also emotional and motivational components, which are essential for meaningful and lasting learning (Urhahne et al., 2023; Hoffman, 2015; Dawson et al., 2009). This paper aims to investigate, through an experimental study involving a sample of students from upper secondary education and an extensive review of the scientific literature, the role of motivation as a predictive variable of school persistence and the potential of AR as a didactic mediator capable of increasing engagement, curiosity, and the joy of learning.

2. The phenomenon of dropout in upper secondary schools in Italy

The phenomenon of dropout in upper secondary schools in Italy represents a structural challenge for the educational system, with significant social and economic implications. According to the most recent data from the Research Office of CGIA of Mestre (2023), over 431,000 young people have left school without completing a diploma or professional qualification. The regions most affected are Sardinia, with a school dropout rate of 17.3%, followed by Sicily (17.1%) and the Autonomous Province of Bolzano (16.2%) (CGIA di Mestre, 2023). At the national level, in 2023, the early school leaving rate stood at 10.5%, showing a decrease compared to previous years (11.5% in 2022 and 12.7% in 2021), yet it remains higher than the European average (Openpolis, 2023). Italy ranks fifth in Europe for school dropout rates, preceded only by Romania (16.6%), Spain (13.7%), Germany (12.8%), and Hungary (11.6%) (Openpolis, 2023). The causes of dropout are multifactorial, involving socio-economic, family, cultural, and individual factors. The situation is particularly critical in the southern regions of Italy, where school dropout rates have historically been higher: historical data indicate, for instance, that in 2012 Sardinia recorded a rate of 25.8%, Sicily 25%, and Campania 21.8% (ISTAT, 2012). To effectively combat this phenomenon, the literature suggests the implementation of integrated and locally tailored interventions, including the strengthening of school guidance activities, the introduction of innovative teaching methodologies, psychological support, and mentoring and tutoring initiatives aimed at reinforcing student motivation and sense of belonging (European Commission, 2020; OECD, 2022).

3. Motivation: A Protective Factor Against Dropout

According to the theoretical framework of Self-Determination Theory (SDT), developed by Deci and Ryan (2000), motivation can be conceptualized as a continuum ranging from full self-determination to a complete lack of motivation, progressing through various forms of regulation depending on the perceived degree of autonomy (Rump et al., 2017). In this model, intrinsic motivation represents the highest level of self-determination, as individuals engage in activities purely for the pleasure and interest they evoke, without any external incentives or rewards. Conversely, extrinsic motivation is structured along progressive forms of internalization: starting with external regulation, where actions are determined by rewards or punishments; followed by introjected regulation, characterized by internal pressures such as guilt or the desire for approval; and culminating in identified regulation, where the individual recognizes and internalizes the values underlying the activity, aligning them with personal goals (Kotera et al., 2023). Although integrated regulation is theoretically considered the most autonomous form of extrinsic motivation, it has not been widely examined in empirical studies due to its statistical overlap with identified regulation (Vallerand et al., 1992). Alongside this taxonomy, SDT distinguishes between autonomous motivation — comprising intrinsic motivation and identified regulation — and controlled motivation, which includes external and introjected regulation (Deci & Ryan, 2000). This distinction has proven crucial in educational contexts, where numerous studies have shown that high levels of autonomous motivation are associated with positive outcomes, such as greater persistence in educational pathways, better academic performance, a lower risk of school dropout, and deeper engagement in learning tasks (Ratelle et al., 2007; Hardre et al., 2003; Renaud-Dubé et al., 2015; Satchell et al., 2017). In contrast, controlled motivation has been linked to surface-level learning behaviours, poor psychological well-being, and increased vulnerability to dropout. Specifically, Ratelle et al. (2007) highlighted that students with high levels of intrinsic motivation and identified regulation demonstrated a stronger ability to maintain commitment to their studies, whereas external and introjected regulation were not robust predictors of persistence. Renaud-Dubé et al. (2015), using mediation models, confirmed the prominent role of intrinsic motivation as a direct predictor of the intention to continue one's studies, while controlled forms of motivation were only weakly correlated or not significant. Moreover, research by Fan et al. (2014) emphasized the protective function of autonomous motivation against dropout, demonstrating that the perception of autonomy and the alignment of academic activities with personal values support sustained effort, even in the face of challenges or setbacks. Overall, scientific evidence converges in identifying autonomous motivation — and particularly intrinsic motivation — as a crucial factor in sustaining the quality and continuity of learning experiences. It represents not only a positive predictor of academic success but also a key resilience factor against school dropout, with profound implications for the design of educational interventions aimed at fostering learning environments that promote autonomy, competence, and a sense of belonging (Deci & Ryan, 2000; Ratelle et al., 2007; Renaud-Dubé et al., 2015; Fan et al., 2014; Kotera et al., 2023).

4. Augmented Reality as a Tool for Promoting Motivation and Learning

Technology plays an increasingly significant role in fostering interest and enjoyment in learning through innovative design and production processes. In an era where digital tools permeate every aspect of daily life, educational practice is called upon to reinvent itself in a technological key, redefining how students learn, interact, and develop skills. Within this framework, AR emerges as a powerful technology that allows the superimposition of virtual elements onto the real world in a three-dimensional, interactive, and real-time format (Cabero-Almenara et al., 2019). AR opens new pedagogical perspectives by providing educators with tools to enrich traditional teaching strategies and promote immersive and meaningful learning experiences (Amores-Valencia et al., 2022). Due to its versatility, AR can be employed through various devices, including head-mounted displays (HMDs), smartphones, tablets, and computers (Khan et al., 2019), facilitating access to complex content in dynamic, visual formats. The use of AR has proven to radically transform learning processes, making them more engaging and active, while fostering the integration of theory and practice (Di Serio et al., 2013). Besides being an affordable and accessible resource (Sabbah et al., 2023; Chin et al., 2019), AR supports experiential learning methodologies and promotes the development of soft skills such as critical thinking, problem-solving, and peer collaboration. Furthermore, AR enables the personalization of educational content according to different cognitive styles, supporting adaptive learning that accommodates individual differences and specific educational needs. Despite the potential of immersive technologies, one of the main limitations of traditional educational practices remains the challenge of sustaining student motivation (Hamari et al., 2014). Rigid and non-interactive teaching strategies, often disconnected from the digital languages of new generations, prove inadequate to meet students' expectations, as highlighted by Sun and Hsieh (2018). In this context, motivation plays a crucial role as a predictive factor of academic performance, persistence in educational pathways, and cognitive productivity. The integration of AR into educational contexts thus emerges as a powerful didactic mediator capable of enhancing intrinsic motivation and fostering active student engagement, laying the groundwork for deeper and more lasting learning. Additionally, the flexibility of AR allows for the creation of inclusive learning environments that address the needs of students with special educational needs. Through the ability to adjust visual intensity, auditory stimuli, and tactile feedback, AR facilitates multimodal and customizable teaching approaches, contributing to the removal of barriers and promoting educational equity. Therefore, the integration of AR into educational processes not only responds to the challenges of contemporary education but also becomes a key ally in promoting academic success and active participation for all students.

5. Research project

This study is situated within an experimental research design aimed at exploring the role of intrinsic motivation as a predictive variable of school persistence, with particular attention to the potential of AR as an innovative instructional mediator. In an educational landscape increasingly oriented towards dynamic, student-centred learning environments, the research seeks to examine the extent to which the integration of immersive technologies may influence key dimensions of motivation, such as active engagement, perceived competence, intentional investment, and the emotional quality of the learning experience. The investigation was conducted on a sample of upper secondary school students, who were involved in an experimental intervention designed to compare two instructional conditions: on the one hand, a traditional approach based on static, paper-based and two-dimensional materials; on the other, a learning pathway enriched by interactive content delivered through AR devices. The primary objective is to understand whether AR can function as a motivational facilitator, supporting student engagement and helping to prevent early signs of school dropout. The motivation experienced under the two conditions was assessed using the Intrinsic Motivation Inventory (IMI), which is structured into four subscales, each targeting specific aspects of intrinsic motivation.

5.1. Research hypothesis

The present study aims to investigate whether the integration of AR as an instructional mediator leads to significant differences in the intrinsic motivation profile of students, compared to a traditional teaching approach. Specifically, the research examines the extent to which AR influences students' experienced motivation across four key dimensions: interest and enjoyment, perceived competence, effort and importance, and pressure or tension.

To this end, the following statistical hypotheses were tested:

- H1a: there is a significant difference between the experimental group (EG) and the control group (CG) in the level of interest and enjoyment reported after the instructional activity;
- H1b: there is a significant difference between the EG and the CG in the level of perceived competence following the learning experience;
- H1c: there is a significant difference between the EG and the CG in the level of effort and importance attributed to the activity;
- H1d: there is a significant difference between the EG and the CG in the level of pressure and tension experienced during the activity.

5.2. Sample

The research involved a total of 36 students attending a public upper secondary school in the Tuscany region of Italy, specifically the "Bianciardi" Art School in Grosseto. The participants were randomly assigned to two equally sized groups: an experimental group (n = 18) and a control group (n = 18). The sample was drawn from four classes belonging to the Architecture and Fine Arts programmes, comprising two third-year classes (n = 16) and two fourth-year classes (n = 20).

As regards gender, the sample included 14 male students (38.9%) and 22 female students (61.1%), as illustrated in Figure 1. In terms of age distribution, participants ranged between 16 and 19 years old, as shown in Figure 2.

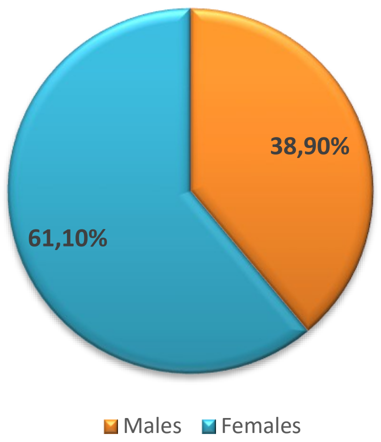

Figure 1. Gender distribution of the sample.

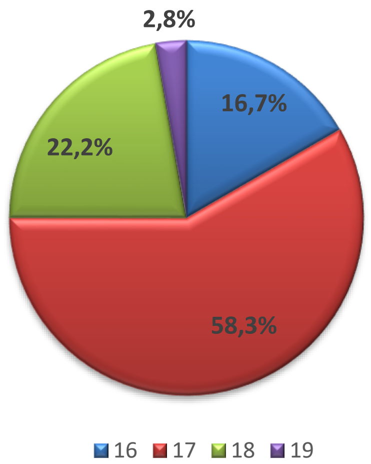

Figure 2. Age distribution of the sample.

The sample also presented a degree of cultural and ethnic diversity: six students were of mixed or non-Italian origin, including Italo-Chilean, Italo-Polish, Italo-Romanian, Peruvian, Ukrainian, and Italo-Venezuelan backgrounds. The remaining participants were of Italian nationality. With respect to their educational profile, 25% of the students had an active Personalised Didactic Plan (PDP). No students with certified disabilities under Italian Law no. 104/1992 were present in the selected classes. Participation in the study was entirely voluntary and not associated with any form of remuneration. Before the beginning of the experimental phase, all students and, where applicable, their parents or legal guardians, provided written informed consent, in full accordance with established ethical standards for research. The processing of all data was carried out in compliance with current privacy and data protection regulations, ensuring the complete anonymisation of the information collected.

5.3. Tools and methods

The study adopted a between-subjects design, in which participants were randomly assigned to either an experimental or a control group, each exposed to a single instructional condition. The intervention required students to engage with a learning topic that was not directly related to their curricular specialisation and, as far as possible, distant from the educational background of the participating population. A theme was deliberately selected that would be neutral in relation to the students' prior knowledge and interests, thereby enhancing the reliability of the assessment of their experienced motivation. For this reason, the study of human brain anatomy was chosen, an area not included in the formal curriculum of the art school but considered suitable for exploration through dynamic and immersive AR visualisation. The control group engaged with the content using a traditional instructional approach, supported by printed materials containing static, two-dimensional illustrations of brain structures (Figure 3). The images provided were identical to those offered to the experimental group, although presented in a conventional paper-based format.

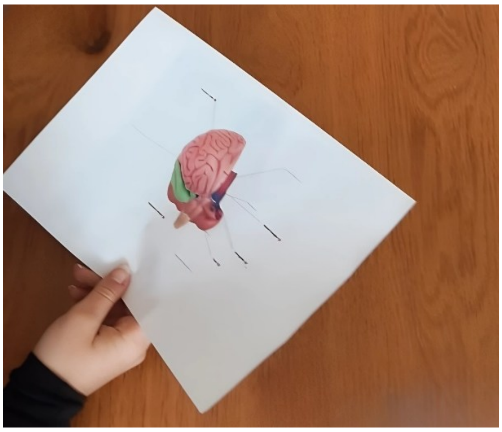

Figure 3. Printed material used by the Control Group.

By contrast, the experimental group accessed AR-enhanced content via a mobile application installed on their personal devices. The AR experience was mediated using the Merge Cube, a physical support that enabled the exploration of three-dimensional brain models in two modes: the “cube” mode, which displayed rotating anatomical models by scanning the cube itself; and the “world” mode, which projected the digital models directly into the physical environment via the device’s camera (Figure 4). This configuration allowed students to virtually manipulate the brain structures in real time, thereby fostering an immersive and tangible experience of the learning object.

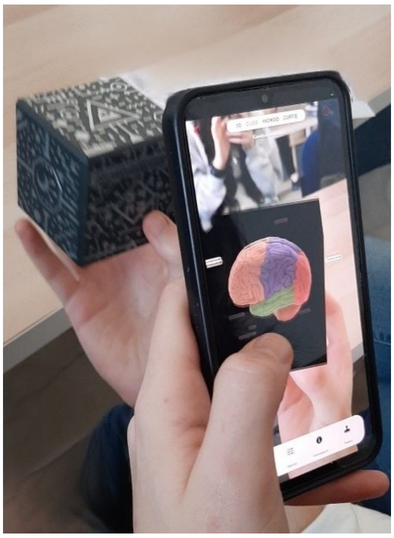

Figure 4. Interaction of the Experimental Group with Merge Cube.

At the end of the instructional phase, students from both groups were asked to complete a questionnaire designed to assess the intrinsic motivation experienced during the learning activity. For this purpose, the Intrinsic Motivation Inventory (IMI) in its standard version was administered. The IMI is a multidimensional instrument developed within the framework of Self-Determination Theory (Deci & Ryan, 1985), aimed at measuring participants' subjective experience in relation to a specific task. In the present study, the standard version comprising 22 items was employed, organised into four subscales. The first, Interest/Enjoyment, is considered the primary indicator of self-reported intrinsic motivation, as it captures the degree of involvement and enjoyment experienced during the activity. The second, Perceived competence, evaluates the individual's sense of efficacy while performing the task. The third, Effort/Importance, explores the level of effort invested in the activity and the value attributed to it. The fourth subscale, Pressure/Tension, assesses the presence of stress or anxiety-related experiences, and is regarded as a negative indicator of intrinsic motivation. The Perceived Competence subscale is considered a positive predictor of intrinsic motivation, both in terms of subjective perception and behavioural outcomes. In contrast, the Pressure/Tension subscale is interpreted as a negative predictor, as it reflects an emotional state that may hinder spontaneous and self-determined engagement. It is important to note that the relationship between effort and intrinsic motivation is not always linear: in some contexts, high levels of effort may signal strong intrinsic engagement, while in others, they may reflect task-related difficulties or lack of familiarity. For this reason, the interpretation of scores on the Effort/Importance subscale requires careful contextual analysis (McAuley, Duncan & Tammen, 1989). Numerous studies have confirmed the validity and reliability of the IMI in both educational and experimental contexts (Tsigilis & Theodosiou, 2003; González-Cutre, Sicilia & Moreno-Murcia, 2008). The statistical analysis was conducted using Jamovi software (version 2.6). In order to examine whether there were statistically significant differences between the experimental and control groups across the four IMI subscales, a Multivariate Analysis of Covariance (MANCOVA) was performed.

5.4. Data analysis and results

Descriptive statistics for the four IMI subscales are presented in Figure 5.

	Group	N	Mean	Median	SD
Interest_Enjoyment_Mean	**CG**	18	3.52	3.50	0.811
	EG	19	4.28	4.29	0.754
Perceived_Competence_Mean	**CG**	18	2.98	2.92	1.405
	EG	19	3.46	3.67	1.320
Effort_Importance_Mean	**CG**	18	3.20	3.10	0.837
	EG	19	3.91	3.80	0.575
Pressure_Tension_Mean	**CG**	18	2.33	2.00	0.726
	EG	19	3.13	3.00	1.128

Figure 5. Descriptive Statistics.

As a general trend, the experimental group exhibited higher average scores than the control group in the Interest/Enjoyment, Perceived Competence, and Effort/Importance subscales, suggesting a more favourable motivational profile following the AR-enhanced instructional experience. Conversely, lower levels of Pressure/Tension were observed in the control group, in line with the theoretical interpretation of this dimension as a negative indicator of intrinsic motivation.

These patterns are further illustrated in the violin plots presented in Figure 6.

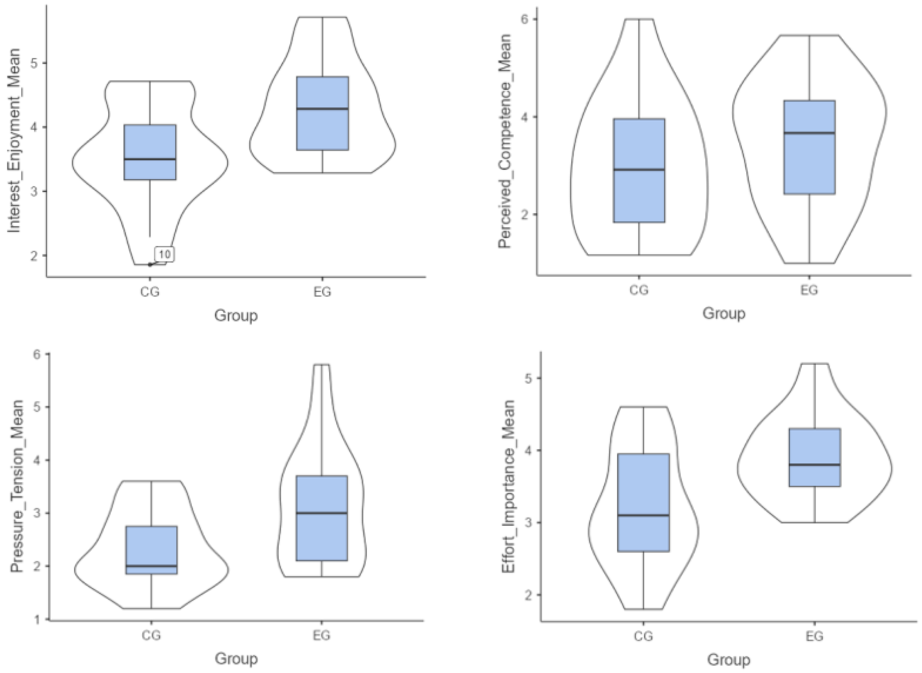

Figure 6. Violin plots of the four IMI subscales.

The violin plots show not only the median and interquartile ranges but also the distribution density of scores within each group. In all three positively associated subscales, the EG distributions appear more concentrated toward the upper end of the scale. For Pressure/Tension, the CG displayed a more compact and lower distribution, whereas the EG presented a wider and higher range of responses. These visual trends suggest the presence of meaningful differences between groups, which were subsequently examined through multivariate analysis. Before conducting the Multivariate Analysis of Covariance (MANCOVA), the main statistical assumptions were tested to ensure the robustness of the results. Multivariate normality was assessed indirectly through the Shapiro-Wilk test applied to the four dependent variables. As shown in Figure 7, no significant violations of univariate normality were detected, indicating that the assumption of normality was met for all IMI subscales.

	W	p
Interest_Enjoyment_Mean	0.974	0.524
Perceived_Competence_Mean	0.980	0.732
Effort_Importance_Mean	0.973	0.502
Pressure_Tension_Mean	0.950	0.093

Figure 7. Shapiro-Wilk Test for Univariate Normality of IMI Subscales.

Homogeneity of univariate variances was verified using Levene's test, conducted separately for each subscale. The results, reported in Figure 8, confirm that variances were equal across groups.

	F	df	df2	p
Interest_Enjoyment_Mean	2.98e-4	1	35	0.986
Perceived_Competence_Mean	0.0431	1	35	0.837
Effort_Importance_Mean	2.3825	1	35	0.132
Pressure_Tension_Mean	3.0861	1	35	0.088

Figure 8. Levene's Test for Equality of Variances Across IMI Subscales.

The homogeneity of variance-covariance matrices was examined using Box's M test. As shown in Figure 9, the result falls within the conservative threshold for acceptability ($p > .001$), supporting the assumption of equality of covariance matrices.

χ^2	df	p
18.3	10	0.050

Figure 9. Box's M Test for Equality of Covariance Matrices.

Finally, the Pearson correlation matrix, in the Figure 10, was analysed to evaluate linearity and the absence of multicollinearity among the dependent variables. The IMI subscales displayed moderate correlations, with no coefficients approaching an absolute value of 1. This indicates no evidence of collinearity or singularity and confirms that the linear relationships among the variables are suitable for inclusion in the multivariate model.

		Interest_ Enjoyment_ Mean	Perceived_ Competence_ Mean	Effort_ Importance_ Mean	Pressure_ Tension_ Mean
Interest_ Enjoyment_ Mean	**Pearson's r**	-			
	df	-			
	p-value	-			
Perceived_ Competence_ Mean	**Pearson's r**	0.592	-		
	df	35	-		
	p-value	<.001	-		
Effort_ Importance_ Mean	**Pearson's r**	0.359	0.163	-	
	df	35	35	-	
	p-value	0.029	0.336	-	
Pressure_ Tension_ Mean	**Pearson's r**	-0.028	-0.328	0.348	-
	df	35	35	35	-
	p-value	0.869	0.048	0.035	-

Figure 10. Pearson Correlation Matrix Between the IMI Subscales.

Overall, the results of the assumption checks indicate that the conditions required to perform MANCOVA were adequately met. Based on these premises, a Multivariate Analysis of Covariance (MANCOVA) was carried out to examine whether the type of instructional approach adopted, namely, the use of AR in the experimental group versus traditional printed materials in the control group, had a significant effect on students' intrinsic motivation, as measured through the four IMI subscales. The multivariate test

(Figure 11) revealed a statistically significant overall effect of the instructional condition on the combined dependent variables (Wilks' Lambda = 0.605, F(4, 32) = 5.22, p = .002), indicating that the motivational profiles of the two groups differed meaningfully.

	value	F	df1	df2	p
Group Wilks' Lambda	0.605	5.22	4	32	0.002

Figure 11. Multivariate test.

Given the significance of the multivariate result, follow-up univariate analyses, shown in Figure 12, were conducted for each IMI subscale to identify the specific dimensions in which the groups differed. The Interest/Enjoyment subscale showed a significant difference between groups [F(1, 35) = 8.78, p = .005], with students in the AR-based condition reporting higher levels of enjoyment and engagement. Similarly, the Effort/Importance subscale yielded a significant effect [F(1, 35) = 9.00, p = .005], suggesting that students in the experimental group invested more effort and attributed greater value to the learning activity. A significant difference was also found in the Pressure/Tension subscale [F(1, 35) = 6.39, p = .016], with lower levels of perceived stress reported by students exposed to the AR-enhanced environment. In contrast, no statistically significant difference emerged in the Perceived Competence subscale [F(1, 35) = 1.12, p = .297], indicating similar self-perceptions of efficacy across groups regardless of the instructional method.

	Dependent Variable	Sum of Squares	df	Mean Squares	F	p
Group	**Interest_Enjoyment_Mean**	5.37	1	5.372	8.78	0.005
	Perceived_Competence_Mean	2.08	1	2.083	1.12	0.297
	Effort_Importance_Mean	4.60	1	4.598	9.00	0.005
	Pressure_Tension_Mean	5.81	1	5.812	6.39	0.016
Residuals	**Interest_Enjoyment_Mean**	21.41	35	0.612		
	Perceived_Competence_Mean	64.93	35	1.855		
	Effort_Importance_Mean	17.87	35	0.511		
	Pressure_Tension_Mean	31.86	35	0.910		

Figure 12. Univariate tests.

These findings support the rejection of the null hypotheses related to H1a, H1c, and H1d, and the corresponding acceptance of the alternative hypotheses. Specifically, the results confirm that the integration of AR significantly influenced students' levels of interest and enjoyment (H1a), their perceived effort and value attributed to the task (H1c), and their experience of pressure and tension during the activity (H1d). In contrast, the null hypothesis for H1b could not be rejected, indicating no significant difference between groups in the dimension of perceived competence.

6. Discussion

This study is framed within the theoretical context of Self-Determination Theory (SDT) developed by Deci and Ryan (1985; 2000), which posits that autonomous motivation, particularly intrinsic motivation, is associated with higher levels of engagement, persistence, and active participation in the learning process, acting as a key protective factor against school dropout (Ratelle et al., 2007; Renaud-Dubé et al., 2015). In parallel, a growing body of research has highlighted the potential of immersive technologies, and AR in particular, as educational tools capable of supporting student motivation through learning experiences that foster engagement, curiosity, and active learning (Garzón, 2021; Lembo et al., 2023). These aspects are also central in addressing the risk of disengagement and dropout in secondary education. Building on this theoretical background, the aim of the present research was to explore whether the integration of AR into teaching and learning processes could generate differences in the motivational profile of students who participated in a traditional learning activity compared to those engaged in an AR-enhanced experience using the Merge Cube. The first hypothesis (H1a) concerned the "Interest/Enjoyment" subscale, considered in the literature to be the primary measure for assessing self-perceived intrinsic motivation (McAuley et al., 1989; Tsigilis & Theodosiou, 2003). The results revealed a significant difference between the two groups, confirming that the learning modality had a substantial impact on the quality of the students' experience. Specifically, the activity conducted with the support of AR appeared to promote higher levels of engagement, likely due to the exploratory, interactive, and immersive nature of the experience, which naturally stimulates students' curiosity and interest, two elements closely linked to intrinsic motivation. Regarding perceived competence (H1b), no statistically significant differences emerged between the two groups. This result may be interpreted in light of several considerations. It is plausible to assume that the task, while technologically innovative, did not require a level of performance capable of eliciting differentiated evaluations of one's abilities. As highlighted by McAuley et al. (1989), perceived competence tends to remain relatively stable in tasks that do not pose a strong cognitive challenge or do not provide specific feedback on individual performance. Furthermore, in the absence of an evaluative or competitive context, it is likely that students experienced a similar level of confidence in their abilities, regardless of the instructional method used. In terms of effort and perceived importance (H1c), the results show a significant difference between the two groups. Students who took part in the activity supported by AR reported investing more effort in the task compared to their peers, suggesting that the teaching modality influenced their perception of the activity's value and their level of commitment. This finding indicates that the innovative approach activated a form of intentional engagement that went beyond initial curiosity. In line with what has been suggested by Lembo et al. (2023) and Fan and Wolters (2014), learning environments that stimulate active participation and foster students' sense of agency over their learning experience can enhance the perceived value of a task and promote intentional and sustained effort. Finally, regarding the emotional pressure and tension perceived during the activity (H1d), the analysis revealed a significant difference between the two groups, suggesting that the adopted teaching method affected the emotional quality of the experience. Students in the experimental condition reported lower levels of pressure and tension than those in the control group. This result aligns with the hypothesis that more engaging, exploratory, and interactive learning environments, such as those involving AR, can help reduce performance anxiety and encourage a more relaxed yet active form of participation (Sabbah et al., 2023). This evidence is particularly noteworthy when considered in relation to the results of the "Interest/Enjoyment" subscale, which also showed a significant difference in the same direction. The lower level of perceived pressure may have served as a facilitating condition, allowing students in the experimental group to focus more fully on the experiential dimension of the activity and derive greater enjoyment from it. Overall, the findings of the present study suggest that AR may serve as an effective educational mediator for supporting the intrinsic motivation of secondary school students, particularly by enhancing interest and effort. These two factors, as highlighted in the literature, are central to sustained and self-determined learning and have been identified as protective variables against school dropout (Renaud-Dubé et al., 2015; Fan & Wolters, 2014). In this perspective, integrating AR into school contexts contributes to the development of dynamic and engaging learning environments that foster students' motivation and, at the same time, represent a strategic preventive intervention against disengagement and school dropout.

7. Conclusions

This study contributes to the current debate on the integration of immersive technologies in educational contexts, highlighting the motivational potential of AR. The findings show that AR, particularly using the Merge Cube, can enrich the learning experience by stimulating key components of intrinsic motivation, such as interest, effort, and emotional well-being. As these dimensions are recognised as protective factors against the risk of school dropout, their enhancement through technological mediation represents a promising preventative perspective. From an applied standpoint, the experimental evidence gathered suggests that the integration of AR in secondary education should be embedded within a pedagogically sound and consciously designed framework, not only to innovate content delivery, but also to support students' motivation, autonomy, and perseverance. Considering the school dropout phenomenon, which remains a critical issue within the Italian education system, these findings underscore the importance of creating emotionally supportive and cognitively stimulating learning environments. The strategic use of AR, when grounded in solid pedagogical principles, emerges as a concrete and viable response to promote students' retention and ongoing engagement with their educational journey.

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