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INTEGRATING VR/AR, ARDUINO AND AI-SUPPORTED PERSONALISATION IN LOWER-SECONDARY STEM EDUCATION: EVIDENCE, RISKS AND IMPLICATIONS

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Abstract. This article presents a structured narrative review of three technologies that are increasingly integrated into STEM education at the lower-secondary level: virtual and augmented reality (VR/AR), open-source microcontroller platforms of the Arduino type, and personalisation supported by artificial intelligence (AI). The review is guided by three questions, concerning the available evidence, the reported risks, and the pedagogical conditions for responsible implementation. It draws on peer-reviewed studies, systematic reviews and meta-analyses indexed in Scopus and Web of Science, as well as on reports of international and national organisations (UNESCO, the European Commission, the OECD and the Bulgarian Ministry of Education and Science). The evidence on motivation, engagement and learning outcomes is summarised together with its limitations – health and age constraints, cognitive overload and the novelty effect, data protection, the digital divide, and a thin evidence base. The review proposes an integrative, pedagogy-centred model and draws conclusions for the design of a future empirical study. For the Bulgarian context, the review further identifies national-level priorities for teacher readiness, including needs assessment, practice-based continuing professional development, mentoring, curriculum-aligned resources and sustained technical and methodological support.

Keywords: STEM education; virtual and augmented reality; Arduino; AI-supported personalisation; lower-secondary education; risks

1. Introduction

The transition from the primary to the lower-secondary level is recognised in the international literature as a period in which the interest of students in science, technology, engineering and mathematics (STEM) often decreases. It is at the age of 11 – 14 years that attitudes are formed which may influence the later choice of educational profile, of higher education and of profession. For this reason, the efforts to maintain motivation and a positive attitude in science at this level have a strategic importance both for the individual student and for a society that faces a shortage of specialists in the STEM fields.

The Bulgarian context adds urgency to this problem. In PISA 2022, the mean science performance of Bulgarian 15-year-olds was 421 score points, against an OECD average of 485, and the country's results were among the lowest it has recorded across the three PISA domains (OECD, 2023a). Bulgaria also participates in TIMSS, which assesses mathematics and science achievement separately, at the fourth and eighth grades (von Davier et al., 2024); the two studies measure different populations and constructs and are therefore reported here separately rather than as a single indicator. Against this background, sustaining interest in the natural sciences – and in the physical sciences in particular – is a recognised national concern. In response, the state has invested considerable resources in the renewal of the educational environment: under the National Programme "Building a School STEM Environment" and procedure BG-RRP-1.015 of the National Recovery and Resilience Plan, with funding of approximately 535 million BGN for 2 271 eligible schools, more than 2000 schools have, according to the National STEM Center, already built STEM centres[2]. This large-scale infrastructural investment places on the agenda the question not of whether, but of how the new technologies are to be used, so that they lead to real learning and not only to a short-lived enthusiasm.

The present article examines three technologies that increasingly appear together in contemporary STEM practice: virtual and augmented reality, open-source microcontroller platforms of the Arduino type, and personalisation supported by artificial intelligence. As these technologies are increasingly used together – for example, when a student programmes an Arduino sensor, visualises the result in a virtual environment and receives personalised feedback from an intelligent system – the need grows for an integral view that encompasses both their combined advantages and the accumulation of their risks. In contrast to reviews that rely solely on scientific publications, the present review deliberately includes reports of international and national organisations as well, since these set the regulatory and ethical framework within which schools operate.

2. Aim and review questions

The aim of this review is to synthesise, in a critical and balanced manner, the evidence and the risks associated with the three technologies, and to derive the pedagogical conditions for their responsible use at the lower-secondary level. The review is organised around three questions.

RQ1. What evidence exists for the effects of VR/AR, Arduino and AI-supported personalisation in lower-secondary STEM education?

RQ2. What risks and limitations are reported for these technologies, in particular for learners aged 11 – 14 years?

RQ3. What pedagogical conditions are necessary for a responsible and effective implementation?

3. Methodological approach of the review

This is a structured narrative review and not a full systematic review; nevertheless, the search and the selection were made transparent in order to strengthen the trustworthiness of the synthesis. The literature was searched in Scopus, Web of Science, ERIC and Google Scholar. The main search terms combined the technology with the educational context – for example, “virtual reality” AND “STEM education”, “augmented reality” AND “science education”, “Arduino” AND “STEM”, and “artificial intelligence” or “adaptive learning” AND “personalisation” AND “school” – restricted, where possible, to the lower-secondary or middle-school level and to the period 2012 – 2026. Peer-reviewed articles, systematic reviews, meta-analyses and reports of recognised organisations were included; purely technical papers without educational outcomes, studies limited to higher education without relevance to school, and non-verifiable sources were excluded. In presenting the findings, a distinction is deliberately maintained between claims based on systematic reviews and meta-analyses, claims based on single empirical studies, and claims based on policy or strategic documents. The main empirical and review literature was limited to publications from 2012 to 2026; the searches were last checked in May 2026. Seminal theoretical works and foundational meta-analyses published earlier, for example Papert (1980) and VanLehn (2011), were included where necessary. As this is a structured narrative rather than a systematic review, an exhaustive record of identified, screened and included items was not maintained, and the selection should be understood as purposive rather than exhaustive. Table 1 summarises the search and selection strategy.

Table 1. Search and selection strategy of the review

Element	Description
Databases	Scopus; Web of Science; ERIC; Google Scholar
Search terms (examples)	“virtual reality” AND “STEM education”; “augmented reality” AND “science education”; “Arduino” AND “STEM”; “artificial intelligence” / “adaptive learning” AND “personalisation” AND “school”
Time span	2012 – 2026
Inclusion criteria	Peer-reviewed articles, systematic reviews and meta-analyses; reports of recognised organisations; relevance to lower-secondary / K-12 STEM; English or Bulgarian
Exclusion criteria	Purely technical papers without educational outcomes; higher-education-only studies without school relevance; studies without learning or affective outcomes; non-verifiable sources
Types of sources	Empirical studies; systematic reviews and meta-analyses; policy and strategic reports

4. Virtual and augmented reality in STEM education

The main pedagogical advantage of VR/AR is rooted in their capacity to make visible and tangible those phenomena that are abstract, dangerous, expensive or impossible to observe in a real classroom. Immersion and the sense of presence engage attention and create an emotional connection with the learning content. A review of virtual laboratories in science, technology and engineering establishes that they widen the access to experimentation and increase engagement, in particular when physical laboratories are inaccessible or risky (Potkonjak et al., 2016). A systematic review of augmented reality in STEM shows that the most frequent benefits are a better understanding of the content, an increased motivation and the development of spatial thinking, with the strongest effects in the visualisation of three-dimensional structures and dynamic processes (Ibáñez & Delgado-Kloos, 2018). The psychological mechanism that stands out is the sense of presence: when the student perceives the virtual environment as real, attention and emotional engagement increase, and abstract concepts acquire a tangible dimension.

The review literature confirms a growing, but still uneven, body of evidence. A scoping review of immersive virtual reality in STEM analysed 41 studies from the period 2009 – 2019 and concluded that most of them describe applications and report positive attitudes of students, whereas systematic measurements of learning achievement remain comparatively rare (Pellas et al., 2020). A systematic review of immersive VR in school and higher education, covering 46 articles, reached a similar conclusion: the technology demonstrates potential for motivation and for the experience of the learner, but the quality of the research designs varies considerably (Pellas et al., 2021). An early and frequently cited review of augmented reality already outlined both its possibilities and the challenges of its implementation in a real classroom (Wu et al., 2013). The cognitive-affective model of immersive learning (CAMIL) provides a useful framework here, specifying the conditions — such as a sense of presence and agency combined with sound instructional design – under which immersion is likely to support rather than hinder learning (Makransky & Petersen, 2021). It is important to underline that the attractiveness of VR/AR must not be confused with learning effectiveness — a question to which the review returns in Section 7.

5. Arduino and project-based STEM learning

While VR/AR operate predominantly in the virtual space, the Arduino-compatible microcontroller platforms return the student to the material world of assembling, measuring and programming real devices. The theoretical basis of this approach is the constructionism of Seymour Papert, according to whom learning is deepest when the child builds a tangible and shareable product (Papert, 1980). The maker movement and the entry of digital fabrication into education broadened this idea, turning cheap open-source electronics into an accessible instrument for invention (Blikstein, 2013).

The empirical literature associates project-based work with Arduino with the development of problem-solving skills, computational thinking, collaboration and creativity. A study of the teaching of programming through embedded computing platforms in secondary education reports increased engagement and a better grasp of algorithmic concepts when the abstract code is connected with the physical behaviour of the device (Merkouris et al., 2017). A systematic review of educational robotics reports generally positive effects on motivation, problem solving and collaboration, but it also points to a heterogeneity of designs and a shortage of rigorous studies (Benitti, 2012). The strong side of Arduino in a STEM context is its integrative character: one and the same microcontroller allows the building of a weather station (physics), a pH-meter or a gas detector (chemistry), an automated greenhouse (biology) and an autonomous robot (engineering), which makes possible the natural connection of school subjects around a common practical task. This corresponds to the very philosophy of the STEM approach, which strives to overcome the artificial separation between disciplines and to place the student in the role of a researcher and a constructor, rather than of a passive recipient of ready-made knowledge.

In contrast to the immersive technologies, Arduino sets higher requirements on time, on the methodological preparation of the teacher and on the management of the class. It can support durable learning through action and a visible, shareable result, although whether this materialises depends on the quality of the task design, the explanation and the assessment. It should also be noted that the evidence reviewed here is relevant to, but not exclusively drawn from, lower-secondary education: relatively few studies focus specifically on ages 11 – 14, and the Arduino-related evidence in particular comes mostly from broader educational-robotics and physical-computing research rather than from Arduino-specific lower-secondary trials. Table 2 therefore summarises a representative sample of the reviewed sources, indicating for each one its type, its learner group, its main findings, its key limitations and its direct relevance to grades 5 – 7.

Table 2. Representative sources on VR/AR and Arduino in STEM education, with type, learner group, limitations and relevance to grades $5^{th} – 7^{th}$

Source	Type of source	Learner group / context	Main findings	Key limitations	Relevance to grades $5^{th} – 7^{th}$
Potkonjak et al. (2016)	Review	Higher ed. & general	Wider access; increased engagement	Few controlled outcome measures	Indirect (not school-specific)
Ibáñez & Delgado-Kloos (2018)	Systematic review	Mixed (school & higher ed.)	Understanding, motivation, spatial thinking	Heterogeneous; short-term	Moderate
Pellas et al. (2020)	Scoping review (41 studies)	Mixed STEM levels	Positive attitudes of students	Few achievement measures	Moderate
Pellas et al. (2021)	Systematic review (46 articles)	K-12 and higher	Potential for motivation	Varying design quality	Moderate–high
Benitti (2012)	Systematic review	School (K-12)	Problem solving, collaboration, motivation	Mixed evidence; few rigorous studies	High (school robotics)
Merkouris et al. (2017)	Empirical study	Secondary education	Engagement; better grasp of algorithms	Single context; short duration	High
Makransky et al. (2019)	Experimental study	Secondary / higher (lab)	More presence, but less learning	Laboratory setting	Indirect (cautionary)
Villena-Taranilla et al. (2022)	Meta-analysis	Primary (K-6)	Positive but moderate effect	Varies by subject; novelty effects	Adjacent (younger ages)

6. AI-supported personalisation in STEM learning

Personalisation is the adaptation of the content, the pace and the form of instruction to the individual profile of the learner. In contemporary practice it relies on several types of artificial intelligence: adaptive learning systems that adjust the level and the sequence; intelligent tutoring systems that provide step-by-step hints and feedback; learning analytics that diagnose gaps; recommendation systems that suggest activities; and, more recently, generative AI. Within the present research project, AI is intended in a deliberately modest role – to diagnose the profile of STEM interest, to recommend suitable VR/AR or Arduino activities, to adjust the level of difficulty and to provide individual feedback — and not to replace the teacher.

The evidence on the effectiveness of such systems is encouraging but conditional. A meta-analysis of 50 controlled evaluations of intelligent tutoring systems found a median improvement of about 0.66 standard deviations over conventional instruction, although the size of the effect depended strongly on the type of test that was used (Kulik & Fletcher, 2016). Earlier work had already shown that well-designed intelligent tutoring systems may approach the effectiveness of human tutoring (VanLehn, 2011). At the same time, comprehensive overviews emphasise that the benefits of AI in education are not automatic and that the technology raises serious pedagogical and ethical questions (Holmes et al., 2019). Crucially, most of this evidence does not come specifically from learners aged 11 – 14, and the broad personalisation strategies summarised below are pedagogical approaches that are not necessarily AI-based; strong claims about the effectiveness of AI-supported personalisation for this age group are therefore not yet warranted. Table 3 summarises these personalisation and differentiation approaches; the direction of the effect is presented qualitatively, since the underlying studies are heterogeneous and do not report comparable effect sizes.

Artificial intelligence amplifies these possibilities, but its potential is inseparable from the risks discussed below. The limitations are particularly important for learners aged 11 – 14 years, whose personal data require special protection and who may be more vulnerable to over-reliance; the international organisations insist that AI cannot be integrated into education without data protection, public debate and an appropriate regulation (UNESCO, 2023b; European Commission, 2022).

Table 3. Personalisation and differentiation approaches (pedagogical strategies, not necessarily AI-based): mechanism and reported direction of effect (qualitative)

Approach	Mechanism	Reported direction of effect
Adaptive content	Adjusts the level and the pace to the learner	Positive; varies with the implementation
Interest-based	Connects tasks to personal interests; offers choice	Positive; among the stronger approaches
Multimodal learning	Visual, auditory and kinaesthetic presentation	Positive; depends on alignment with content
Project-based	The learner chooses and owns a practical task	Positive; supported by autonomy and engagement

7. Risks and limitations

A balanced review requires that the risks be presented with no less attention than the benefits. They may be summarised in five groups: health and age-related; cognitive; connected with data, privacy and ethics; connected with equity, access and teacher preparation; and connected with the quality of the evidence base itself.

7.1. Health and age-related risks

The immersive technologies raise specific health questions, in particular for children whose visual and vestibular system is still developing. The most frequently described side effect is the so-called cybersickness – nausea, dizziness, headache and fatigue that arise from a mismatch between the perceived motion and the sensations of one's own position. The manufacturer of the most widespread VR headsets explicitly warns that prolonged use may lead to blurred or double vision and to strain of the eyes and the muscles, that the weight of the device may burden the neck and the back of the child, and that the visual system of younger children may be negatively affected[1]. The same manufacturer lowered the recommended minimum age for the use of the devices from 13 to 10 years, introducing parent-managed accounts for children between 10 and 12 years[1]. This change is contested by consumer-protection organisations and child-health experts, who point to a risk of access to inappropriate content, an insufficient scientific study of the long-term effects, and a necessity of strictly limiting the time of use (U.S. PIRG Education Fund, 2023). For the target group of 11 – 14 years these warnings are directly relevant and impose strict practical rules: short sessions with regular breaks, parental consent and supervision, individual adjustment of the device, immediate interruption at the appearance of symptoms, and alternative, non-immersive activities for students who experience discomfort.

If VR/AR is used excessively and without pedagogical and adult control, the immediate risks of cybersickness, visual fatigue and musculoskeletal discomfort may increase and may be compounded by cognitive overload, exposure to inappropriate content, reduced physical activity and the displacement of face-to-face or hands-on learning (U.S. PIRG Education Fund, 2023; UNESCO, 2023a). Therefore, for learners aged 11 – 14, VR/AR should be treated as a time-limited instructional episode rather than as a default learning environment, with documented duration limits, active supervision, symptom checks and an equivalent non-immersive alternative.

7.2. Cognitive risks and the novelty effect

More subtle, but no less important, is the risk that a high degree of immersion may harm learning instead of supporting it. Experimental studies show that adding immersive virtual reality to a science simulation increases the sense of presence, but may decrease the acquisition of knowledge in comparison with simpler formats, because the rich sensory environment distracts attention and increases the cognitive load (Makransky et al., 2019). Comparisons between learning in virtual reality and through a traditional presentation establish that VR is often more engaging, but not always more effective for memorising and understanding, unless it is combined with purposeful strategies for the active processing of information (Parong & Mayer, 2018); the cognitive-affective model of immersive learning systematises the conditions under which immersion leads to learning and underlines the role of the pedagogical design (Makransky & Petersen, 2021). To this is added the novelty effect: the initial enthusiasm from an unfamiliar technology may inflate the measured results in short studies, without being preserved over time. A meta-analysis of the influence of virtual reality on learning outcomes at the primary stage finds an overall positive, but moderate, effect that varies by subject and design (Villena-Taranilla et al., 2022). The conclusion for practice is that the technology in itself does not guarantee learning; decisive are the pedagogical framework, the duration of the intervention and the combination of immersive moments with structured reflection.

7.3. Data, privacy and ethics

Personalisation through artificial intelligence and immersive environments collect considerable volumes of personal data about minors – from learning results to biometric signals such as the movements of the head and the gaze. UNESCO issued the first global guidance for generative artificial intelligence in education, recommending the protection of personal data, the training of teachers and an age limit of 13 years for the independent use of generative AI platforms by students (UNESCO, 2023b); the document builds on the Recommendation on the Ethics of Artificial Intelligence (UNESCO, 2021) and warns that the uncontrolled entry of AI may harm the development of critical thinking and creativity. The European Commission published ethical guidelines for the use of artificial intelligence and data in teaching and learning, intended for teachers, which require transparency, human oversight and respect for privacy (European Commission, 2022). The legal framework requires careful interpretation. Under the General Data Protection Regulation (GDPR), Article 8 sets the age at which a child may consent to information-society services; Bulgaria, through Article 25c of its Personal Data Protection Act, has set this age at 14, below which the consent of a parent or guardian is required[3]. In a school setting, however, consent is frequently not the appropriate lawful basis: processing more often rests on a public task or a legal obligation, with the school acting as data controller. Whichever basis applies, the principles of data minimisation, purpose limitation and defined retention and erasure periods must be observed. Systematic monitoring and certain uses of eye- and head-tracking data in XR devices may create a high risk to the rights and freedoms of learners and may therefore require a data protection impact assessment before processing (Article 35 GDPR). Such data constitute special-category biometric data under Article 9 GDPR only where they are processed for the purpose of uniquely identifying a natural person. The need for a data protection impact assessment should be assessed case by case by the controller, taking account of the scope, purposes, categories of data and safeguards, with the involvement of the data protection officer and, where required, the Commission for Personal Data Protection. UNESCO also insists that online connections cannot replace live communication and that technology must support, and not displace, teacher-led instruction (UNESCO, 2023a).

7.4. Equity, access and teacher preparation

The Global Education Monitoring Report of UNESCO formulates three system-wide conditions, without which no technology can unfold its potential: access to the technology, governance and regulation, and the preparation of teachers (UNESCO, 2023a). The high price of immersive equipment and of its maintenance carries a risk of deepening the digital divide between schools and regions. The OECD likewise emphasises that an effective digital transformation of education depends on the building of a complete ecosystem, and not on separate devices (OECD, 2023b). For Bulgaria, the large-scale investment in STEM centres creates a favourable material basis, but its success will depend on how far teachers are methodologically prepared to use the new environment and how far access is evenly distributed.

This review did not identify representative national data that would justify a general conclusion that Bulgarian teachers are adequately prepared to use Arduino as a teaching tool in STEM centres; readiness should therefore be regarded as an empirical question and is likely to vary across schools. Such readiness involves more than elementary coding: it includes safe work with circuits, sensors and power sources, the design of curriculum-aligned inquiry and engineering tasks, the management of collaborative project work, the diagnosis of hardware and software faults, and assessment of both process and product.

7.5. Quality of the evidence base

Finally, the evidence base itself deserves a critical look. The UNESCO report notes that reliable evidence for the added value of digital technologies in education is scarce, that educational technology products change on average every 36 months – faster than it is possible to evaluate them – and that decisions on implementation are rarely based on independent data; in one survey only 11% of the questioned educators and administrators requested peer-reviewed evidence before the adoption of a given product (UNESCO, 2023a). A large part of the studies are short-term, with small samples and without control groups, and the positive results are exposed to a risk of publication bias. These limitations do not deny the potential of the technologies, but they justify caution and underline the need for methodologically sound and more prolonged studies with a control group. The same caution applies to the qualitative summaries in Table 3, which draw on heterogeneous studies and should be regarded as an orientation for tendencies, and not as exact estimates of effect. Table 4 systematises the main groups of risks, the corresponding guidelines and concrete measures for their mitigation, together with their relevance for grades 5th – 7th.

Table 4. Risks, guidelines, mitigation measures and relevance for grades $5^{th} – 7^{th}$

Risk	Guidelines / source	Measures for mitigation	Relevance for grades $5^{th} – 7^{th}$
Health and age-related (cybersickness, vision, neck strain)	Meta (Note 1); U.S. PIRG (2023)	Short sessions and breaks; consent; age-appropriate use; stop at symptoms	High – parent-managed accounts may be available for ages 10 – 12; health evidence for this age group remains limited
Cognitive overload and novelty effect	Makransky et al. (2019); Parong & Mayer (2018)	Stable design; active-processing strategies; longer interventions	High – short attention span; strong novelty reaction
Data protection and privacy	UNESCO (2023b); European Commission (2022); Bulgarian PDPA (Note 3); GDPR	Documented lawful basis; data minimisation; retention limits; risk assessment and DPIA where processing is likely to result in a high risk (e.g., extensive monitoring or identifiable biometric data).	High – minors; the age threshold of 14 applies where consent is the lawful basis; parental consent is required below that age.
Digital divide and teacher preparation	UNESCO (2023a); OECD (2023b)	Even access; continuing teacher training	Medium – depends on school resources
Insufficient evidence base	UNESCO (2023a)	Control groups; validated instruments; long-term evaluation	Medium – few studies on this age group

8. Implications for Bulgarian lower-secondary STEM education

The review has direct implications for the Bulgarian context. The large-scale investment in school STEM centres provides a material basis that is, at present, comparatively rare at the European level: according to the National STEM Center, more than 2000 schools have already built such centres[2]. The analysis above suggests, however, that the sustainable effect of this investment will depend less on the equipment itself and more on three conditions. First, the methodological preparation of teachers, who must be able to embed VR/AR and Arduino activities within a coherent pedagogical design, rather than use them as isolated novelties. Second, the alignment of the activities with the national curriculum and with valid forms of assessment, so that the engagement created by the technology is converted into measurable learning. Third, a clear framework for the protection of the data of minors and for the safe use of immersive devices. This research is conceived in this spirit: it treats the three technologies not as ends in themselves, but as means whose value is realised only through the mediation of the teacher and within an ethically governed environment. At national level, infrastructure investment should therefore be matched by a staged teacher-development programme: a national needs assessment; practice-based modules and micro-credentials; regional mentor and school networks; open, curriculum-aligned banks of tested Arduino and VR/AR activities; ongoing technical and methodological support; and evaluation of whether training transfers into classroom practice (UNESCO, 2023a; OECD, 2023b). Participation should include protected time for lesson design and peer observation, so that training is connected to actual teaching rather than limited to one-off equipment demonstrations.

9. Conceptual model and future empirical study

Figure 1 presents an integrative conceptual model that summarises the logic of the review. The three technologies do not influence motivation, engagement and learning outcomes directly, but through the quality of the pedagogical design, the mediation of the teacher and the forms of assessment; ethical governance and the mitigation of risks act as a necessary supporting condition.

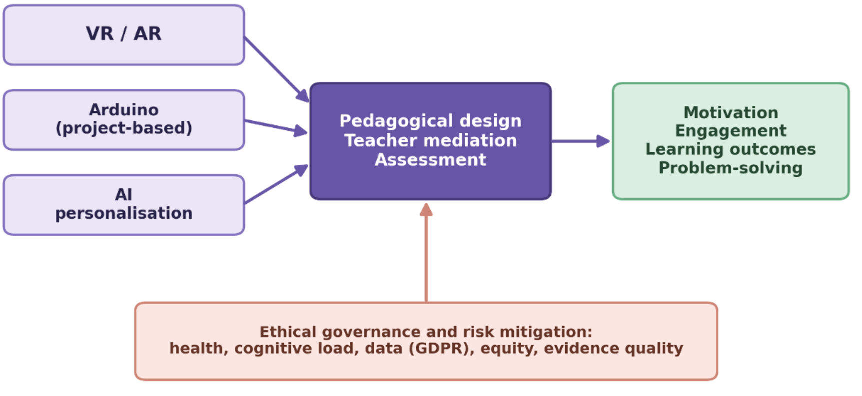

Figure 1. Integrative conceptual model: technologies, pedagogical mediation, outcomes and ethical governance

From this model several requirements follow for future empirical study. The design should include a control group and validated instruments, in order to separate the real effect from the novelty effect; the intervention should be of a sufficient duration in order to trace the durability of the effects; the use of immersive devices requires explicit protocols for safety, parental consent and limitation of the time of use; and the processing of data of minors must follow the principles of UNESCO and of the European Commission and be in accordance with the GDPR. The study should also record VR/AR exposure duration and adverse symptoms and include a baseline measure of teachers' Arduino-related technical and pedagogical readiness.

10. Conclusion

The review of the scientific literature and of the documents of international and national organisations outlines a consistent picture. Virtual and augmented reality, the Arduino platforms and personalisation through artificial intelligence possess a real potential to increase the motivation, the engagement and certain learning outcomes of students at the lower-secondary level, but this potential is conditional upon a stable pedagogical framework, attention to the age-related and health characteristics of children, the protection of their data, and prepared teachers. In this way the review fulfils a twofold function: it systematises the grounds for the implementation of the three technologies in Bulgarian STEM education and, at the same time, it outlines the precautionary framework within which this implementation may be both inspiring and responsible. Future studies should combine quantitative and qualitative methods, take into account the specificity of the 11 – 14 age group, and trace the effects over time, in order to distinguish durable learning from short-lived enthusiasm. For Bulgaria, this means that investment in equipment should be accompanied by a coordinated national system for needs-based, practice-oriented teacher development and sustained school-level support.

NOTES

1. Meta Platforms. Meta Quest safety centre and parent information. https://www.meta.com/quest/parent-info/ (accessed June 2026).
2. Ministry of Education and Science. National Programme "Building a School STEM Environment" and procedure BG-RRP-1.015 of the National Recovery and Resilience Plan (approx. 535 million BGN; 2 271 eligible schools). National STEM Center: https://stem.mon.bg/ (accessed June 2026).
3. Personal Data Protection Act of the Republic of Bulgaria (Закон за защита на личните данни), promulgated State Gazette No. 1/2002, last amended SG No. 17/2019; Article 25c (age of consent – 14 years) and Article 35 GDPR (data protection impact assessment). Supervisory authority: Commission for Personal Data Protection.

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