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METHODOLOGICAL JUSTIFICATION FOR AI-INTEGRATED STEAM EDUCATION IN THE EDUCATIONAL PROCESS FOR FUTURE PROFESSIONALS IN THE PUBLISHING AND PRINTING INDUSTRY

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Abstract. *This paper examines the theoretical and methodological foundations for integrating AI into STEAM education for the training of future professionals in the publishing and printing industry. It demonstrates how combining the interdisciplinary STEAM approach with the modern capabilities of artificial intelligence can enhance the effectiveness of vocational education. The main principles of organising such training are outlined – integrity, practical focus, flexibility and a focus on innovation – and the pedagogical conditions for developing professional competencies in the field of digital publishing are defined. Particular attention is paid to the use of AI technologies in editorial and printing processes, specifically in design, typesetting, information processing and personalised learning. An approach to integrating artificial intelligence into the STEAM educational environment is proposed, which promotes the development of creativity, technical thinking and the capacity for innovative activity.*

Keywords. *AI integration, steam education, methodological rationale, publishing and printing industry, vocational training, digital technologies, artificial intelligence, interdisciplinary approach, educational innovations, competence-based approach.*

Introduction

Modern changes in the publishing and printing industry are due to the development of digital technologies, automation of production processes and the growing role of AI. This requires a reformatting of approaches to training future specialists in the publishing and printing industry. Specialists must possess not only traditional knowledge, but also skills in working with intelligent systems and creatively solving complex tasks. In this regard, the integration of STEAM education with AI technologies as a basis for the formation of interdisciplinary thinking and innovative competence is of particular relevance.

AI-integrated STEAM opens up new opportunities for reformatting the educational process, combining the main elements of scientific, technical, engineering, artistic and mathematical approaches with AI tools. Such an approach contributes to the setting up of an adaptive, practice-oriented learning environment in which students can develop as professionals. At the same time, the implementation of AI in STEAM education requires a clear methodological justification, definition of principles, approaches, and pedagogical conditions that ensure the effectiveness of this process.

The effectiveness of VR tools in higher education institutions is determined by the synergy of methodologically sound design and consideration of the discipline-specific nature of knowledge. Given the technological complexity of developing such systems, the analysis of their functional typology takes on particular importance. It is the classification approach that allows for the optimization of the process of selecting VR solutions, ensuring their appropriateness and effectiveness in the implementation of specific educational models.

The purpose and objectives of the research

The aim of the study is to establish the theoretical foundations and develop methodological approaches for integrating artificial intelligence (AI) tools and immersive technologies (AR/VR/MR) into the interdisciplinary course design process for third-year undergraduate students majoring in G20 "Publishing and Printing," which will ensure the development of professional competencies in the context of modern digital challenges.

The object of the study is the process of professional training for third-year undergraduate students majoring in G20 "Publishing and Printing" in the context of the digitalization of the educational environment.

The subject of the study is the methodological principles, content, and tools for integrating STEAM elements (in particular AI and immersive technologies) into the structure of interdisciplinary course design as a means of creating interactive media content.

Main part

1 Analysis of current research

In contemporary scientific literature, the issue of virtualizing education is examined from multiple perspectives. In particular, the impact of immersion depth on cognitive development and the effectiveness of educational applications has been analyzed by M. A. Kukhail [7], K. Schott, and S. Marshall [8]. The technical and technological basis of VR systems, their operational methodology, and user interaction tools are presented in the publications of H. Martin-Gutiérrez [10] and A. H. Juman [11]. Alongside the broad possibilities for applying immersive content, researchers (V. Chung, M. Barnett-Cowen) emphasize the need to account for ergonomic factors, particularly the prevention of negative somatic reactions in users [9].

The development of STEM education in Ukraine is currently gaining momentum. The Ukrainian government has developed a series of regulatory documents to ensure the sector's effectiveness: the approval of the Concept for the Development of Science and Mathematics Education (STEM Education) and the Action Plan for Implementing the Concept for the Development of STEM Education through 2027; approval of the Standard List of Teaching Aids and Equipment for Classrooms and STEM Laboratories [6].

2 Theoretical and Methodological Foundations for the Use of AI and Immersive Technologies in the Publishing and Printing Industry

Modern educational technologies facilitate educators' use of the guiding principle of STEM education-integration (transdisciplinary). To implement educational technology in the teaching process, teachers must create certain optimal conditions, namely: tolerant, interpersonal, democratic interaction that fosters a humanistic and dialogic communication style; a relevant problem-based situation that will stimulate productive, creative activity among learners; the use of interactive, scientific, and design-based teaching methods; and group work that will foster an atmosphere of cooperation, co-creation, and self-realization for each individual [2].

Despite operating under martial law, educators at Ukrainian educational institutions continue to effectively implement modern models for organizing the educational process. Ensuring the high-quality modernization of the learning process requires clear and timely decisions, accessible explanations, and the introduction of innovative forms of education, including the implementation of STEM education within a blended learning model. Modernizing educational content ensures the training of a new generation of specialists capable of adapting to contemporary conditions of social mobility and mastering cutting-edge professional technologies [3].

2.1 A Conceptual Analysis of the Synergy Between Artificial Intelligence and AR/VR Technologies in Training the Next Generation of Specialists.

The current stage of development in the publishing and printing industry is characterised by a rapid blurring of the boundaries between traditional static products and dynamic digital environments. At the heart of this transformation lies the conceptual synergy of the two most powerful technological drivers of our time: artificial intelligence (AI) and immersive technologies (AR/VR/MR).

In this context, artificial intelligence acts not only as a tool for automating routine processes, but as an intellectual core for generating and personalising content. At the same time, augmented and virtual reality technologies provide a fundamentally new plane for its visualisation and perception, transforming the reader or consumer from a passive observer into an active participant in interactive engagement.

For the new generation of specialists in the G20 discipline 'Publishing and Printing', understanding this synergy is becoming a critically important professional skill. The educational challenge lies in the transition from linear training to an integrated learning model, where the technical precision of print production is combined with the algorithmic flexibility of AI and the spatial design of immersive environments.

A conceptual analysis of such interaction allows us to define the theoretical boundaries of the 'new media product', where:

– AI is responsible for intellectual content, adaptability and the speed of creating complex visual assets;

– AR/VR create an immersive interface that extends the physical properties of printed or digital products;

– The STEAM approach provides a methodological framework for integrating these elements into a coherent system within the context of course design.

Thus, examining the synergy of these technologies within the theoretical section is a necessary step towards developing a new educational strategy that meets the dynamic demands of the modern media and publishing industries.

STEAM fosters the development of creative thinking, encourages a keen interest in gaining a deep understanding of the subject matter, and develops critical thinking. As a result, higher education students acquire not only knowledge but also essential skills, a thirst for knowledge, motivation for self-development, and an enthusiasm for the learning process itself.

In [1], data on the use of educational technologies by teachers based on a person-centred approach in the context of implementing STEM education are presented in Table 1. To enable data comparison, comparative analysis and generalisation, the figures are given as percentages (%).

Empirical data confirm the dominance of project-based, group-based and creative-developmental technologies in teaching practice. Respondents emphasise the high didactic effectiveness of collaborative learning, where joint creative activity and the teacher's facilitative approach act as catalysts for students' intellectual development. This format of interaction forms the foundation for the implementation of project-based technology, which integrates research with the practical mastery of scientific methods, critical analysis of results, and the development of a holistic scientific worldview in future specialists.

Table 1 – Data on the use by higher education lecturers of educational technologies based on a person-centred approach in the educational process. Compiled on the basis of [1]

Technology area	Key authors and concepts	Proportion of the course project (%)	Functional role in a STEAM context
Project-based learning	J. Dewey, W. H. Kilpatrick (Project Technology)	30%	Basic framework for the course project: from idea to finished media product
Team and group work	I. G. Pestalozzi, J. Dewey (Group activities)	20%	Developing soft skills: role distribution (designer, technologist, prompt engineer)
Creative and developmental	E. M. Ilyin, I. P. Volkov (The Formation of the Creative Personality)	20%	Working with AI tools to create a unique visual style
Research-based	M. V. Klarin, V. V. Bukhvalov (Learning as Research)	10%	Testing AR markers and experimenting with print materials
Cognitive and psychological	L. Vygotsky (Developmental Learning)	10%	Focusing on the 'zone of proximal development' when mastering complex software
Humanistic and didactic	Sh. A. Amonashvili (The Pedagogy of Cooperation)	10%	The 'Teacher–Student' interaction model as equal researchers
TOTAL		100%	

Overall, STEAM education produces professionals who not only possess in-depth technical knowledge but are also capable of approaching complex problems creatively, adapting to new circumstances and working in multidisciplinary teams. This makes it an extremely important component of the modern education system.

2.2 The theoretical basis for the interaction between artificial intelligence and immersive environments within the context of the interdisciplinary STEAM paradigm.

A theoretical re-examination of the process of training modern specialists in the publishing and printing industry requires a shift away from traditional teaching approaches towards multidimensional learning models. The foundation of such an update is the interdisciplinary STEAM paradigm, which in the digital age is transforming into a complex ecosystem where artificial intelligence (AI) and immersive environments (AR/VR) serve not merely as auxiliary tools, but as integrative hubs of knowledge.

The interaction of AI and immersive technologies within the STEAM approach creates a new theoretical framework, where each element of the acronym takes on specific meaning for a graphic designer:

– Science: Research into machine learning algorithms and the optics of virtual space perception;

– Technology: Practical application of software suites for creating interactive content;

– Engineering: Designing the architecture of interaction between the physical medium (printed publication) and the digital layer;

– Arts: The aesthetics of generative design and visual dramaturgy in an immersive environment;

– Mathematics: Computational logic of prompt engineering and the geometry of 3D modelling.

The theoretical basis for this interaction rests on the principle of technological convergence. In this model, artificial intelligence acts as a ‘generator of meanings and forms’, whilst immersive environments provide a ‘living space’ for these forms. For higher education students, this approach signifies a shift from the reproductive acquisition of knowledge to constructive interdisciplinary design, where the final product is the result of the synthesis of code, algorithm and physical embodiment.

Thus, examining the interrelationship between AI and AR/VR through the prism of the STEAM methodology allows for the formation of a holistic concept of learning that prepares higher education students to work in the conditions of high uncertainty and technological complexity of the modern media market. This creates the necessary conditions for the implementation of complex interdisciplinary course projects that combine traditional print quality with innovative interactivity.

2.3 International practices and domestic trends in the integration of intellectual and immersive content into the educational environment of STEAM-oriented disciplines.

Modern higher education in the field of publishing and printing is undergoing a global transformation driven by the transition to Industry 4.0. An analysis of the global educational landscape shows that leading technology universities are increasingly moving away from narrowly specialised training in favour of comprehensive STEAM-oriented models, where intellectually immersive content becomes the main focus of research and design.

Global practice (in particular, the experience of universities in the US, Germany and the UK) demonstrates a consistent trend towards the implementation of 'digital twins' of printing processes and the use of generative artificial intelligence to optimise pre-press preparation. International case studies confirm that involving students in the creation of augmented reality (AR) projects not only enhances technical literacy but also stimulates the development of creative thinking, which is critically important for future media industry professionals.

Positive trends in adapting to these challenges are also evident in the Ukrainian educational landscape. Despite challenging external conditions, domestic higher education institutions are actively integrating elements of immersion into the curricula for third-year undergraduate students (Bachelor's level) in the G20 specialisation 'Publishing and Printing'. However, infrastructure limitations and the need to update teaching methods often stand in the way.

The study of experiences in implementing artificial intelligence as a means of 'intellectual support' for content development is becoming particularly relevant. Domestic higher education is gradually moving from the sporadic use of digital applications to the systematic application of AI and VR within interdisciplinary projects. This enables third-year students to develop a holistic view of the modern publishing product as a high-tech, multimodal entity.

A comparative analysis of international practices and domestic realities in this section will help identify the optimal ways to integrate innovative technologies into the structure of course design, taking into account both global technological standards and the specific nature of specialist training in Ukraine.

3 Methodology for integrating intelligent and immersive tools into interdisciplinary course design

3.1 Transforming the structure and content of the course project in light of the challenges posed by digitalisation and content interactivity.

The transition of the publishing and printing industry to the 'Smart Media' model calls for a radical rethinking of traditional approaches to the practical training of third-year undergraduate students (Bachelor's degree) in the G20 specialisation 'Publishing and Printing'. A key stage of this training in the third year is an interdisciplinary course project, which, in today's context, is no longer merely a test of knowledge of typesetting or printing technology, but has evolved into a comprehensive study of the life cycle of an interactive product.

The challenges of global digitalisation dictate the need to transform both the structure and the content of the course project. Whereas previously the dominant output was a static paper format (a book, magazine or newspaper), today the focus is shifting towards the creation of a multimodal object that combines a physical medium with a digital interactive layer. This transformation necessitates the expansion of the project's structure to include new stages: from the development of an architecture for immersive interaction to the integration of media assets generated using artificial intelligence.

The content of the course project must be adapted to the following key factors:

– Interactivity as standard: treating the publication not as a closed information system, but as an interface for accessing extended content (AR/VR applications, animated elements);

– Hybrid processes: combining traditional printing standards (colour space, resolution, bleed) with the requirements of digital platforms;

– Algorithmisation of creativity: using AI tools during the stages of concept development, generation of illustrative material and layout optimisation.

The transformation of the course project structure allows students to move beyond a narrowly technological approach and try their hand at being architects of the media space. This creates the conditions for developing a specialist capable not merely of overseeing the printing process, but of designing a holistic interactive user experience, which is a fundamental requirement of the modern media market.

This section analyses how the stages of coursework completion are changing and what new requirements are being placed on the learning outcomes of third-year undergraduate students (Bachelor's level) in the G20 specialisation 'Publishing and Printing' in the context of contemporary technological challenges.

Before integrating STEAM elements, it is necessary to carry out a detailed analysis of the current interdisciplinary course project undertaken by third-year students on the G20 'Publishing and Printing' programme at the first (bachelor's) level of higher education.

It is important to assess the extent to which its content meets modern technological and educational requirements, and to identify key topics and teaching methods. This will help to understand which STEAM elements can organically complement the learning process, and which require substantial revision or improvement.

The assessment of the existing structure and content of the interdisciplinary course project may be based on the following criteria.

1. Analysis of alignment with the curriculum:

– determining the alignment of the content of the interdisciplinary course project with the standards of the G20 specialism 'Publishing and Printing';

– analysis of the cross-cutting competences embedded in the curriculum.

2. Structural analysis:

– verification of the logical structure of the interdisciplinary course project (introduction, theoretical section, practical calculations, conclusions);

– assessment of the balance between theoretical and practical components.

3. Content analysis:

– analysis of the use of modern technologies and methodologies in the publishing and printing process;

– determination of the depth of coverage of the disciplines integrated into the project.

4. Practical significance:

– analysis of the practical value of the interdisciplinary course project (whether it is a realistic project that can be implemented in practice);

– identification of possible areas for improvement.

5. Assessment methods:

– surveying higher education students and lecturers regarding the effectiveness of the interdisciplinary course project;

– analysing reviews and feedback on previous course projects;

– comparison with similar courses at other educational institutions.

This approach allows for a structured analysis and makes the evaluation of the course project more objective.

3.2 Classification and selection of artificial intelligence tools and immersive technologies for the creation of multimedia publications.

Based on the analysis carried out, it is necessary to identify the most effective tools that can be used in the teaching process. These may include:

– Software for 3D modelling and design (AutoCAD, Blender, Adobe Creative Suite);

– Interactive platforms for learning to code (Scratch, Python, JavaScript);

– The use of augmented reality (AR) technologies in the development of print products;

– The integration of machine learning and artificial intelligence to automate typesetting processes and the analysis of text data.

The effectiveness of implementing an interdisciplinary course project in today's environment depends directly on the informed selection of a software and technology stack. The rapid evolution of digital services has led to the formation of a diverse ecosystem of tools, in which generative artificial intelligence (GenAI) models and platforms for developing immersive content (AR/VR/MR) play a key role. For students of the 'Publishing and Printing' programme, it is critically important not only to navigate this diversity but also to select the appropriate tools in accordance with the technological requirements of the publishing product.

Classifying modern tools within the STEAM approach allows software tools to be structured according to their functional purpose.

1. Intelligent tools for generating and processing media assets: neural networks for creating text content and high-quality raster and vector illustrations, as well as AI upscaling tools for preparing high-resolution images for print.

2. Tools for designing immersive interactions: specialised software for creating augmented reality (AR), enabling the integration of digital objects into the physical space of a printed page via marker-based or markerless tracking systems.

3. Integration platforms: environments that ensure synergy between traditional publishing layout and interactive overlays, enabling the creation of a cohesive multimedia experience.

The selection of specific tools for course design should be based on the principles of accessibility, cross-platform compatibility and compatibility with classic printing standards. The choice between professional engines (such as Unity) and cloud-based WebAR solutions, or between different models of diffusion neural networks (such as Midjourney or Stable Diffusion), determines not only the visual quality of the publication but also the architecture of the entire interdisciplinary interaction.

This section proposes a systematisation of current AI and AR tools, adapted to the needs of the educational process, and defines the criteria for their selection to create innovative multimedia publications that meet the contemporary challenges of the media market.

The traditional structure of the interdisciplinary course design project for third-year undergraduates studying the G20 ‘Publishing and Printing’ at the first (bachelor’s) level of higher education is based on a threefold task: developing an artistic and technical concept, calculating technological parameters, and designing the production process with the selection of appropriate equipment. However, in the context of the industry’s digital transformation, this foundation requires the integration of STEAM tools, which allow for the combination of classical engineering precision with the capabilities of artificial intelligence and immersive content.

A comprehensive approach to learning within the context of design is implemented through the following levels of integration.

1. Intellectualisation of pre-press processes (AI-driven Prepress).

Artificial intelligence is integrated not only as a means of generating illustrations, but also as an analytical tool for automating layout checks, optimising page layout and forecasting material consumption.

The use of intelligent algorithms (for example, for image upscaling or colour profile correction) enables third-year students to improve the technical quality of the product whilst minimising the human factor.

2. Design of an immersive augmented reality product (AR-Extension).

A printed publication is no longer merely a printed object. The project now includes a stage involving the development of a ‘digital twin’ of the publication or an AR app. This requires the applicant to possess skills in designing interactive experiences, where the printed page acts as a trigger (marker) to activate immersive content. This stimulates the development of engineering thinking in the context of programming and 3D modelling.

1. Technical calculation for hybrid publications.

The selection of equipment and cost calculation now covers not only the printing cycle (offset or digital printing), but also the resources required to support cloud services for immersive content. The applicant must justify the choice of paper and inks not only from an aesthetic point of view, but also in terms of technical suitability for reading AR tags with mobile device cameras (taking into account glare, contrast and texture).

2. Synergy of STEAM elements.

Science & Math: calculation of optical parameters and image recognition algorithms.

Technology: use of AI platforms and AR engines.

Engineering: design of a holistic ‘publication – app – user’ system.

Arts: creation of a visual concept where the real and virtual worlds harmoniously complement one another.

Thus, the integration of AI and immersive technologies into an interdisciplinary project enables the transformation of the training of future specialists from ‘technical implementers’ to ‘architects of intelligent media systems’. This ensures that the educational process meets the current challenges of the market, where demand for interactive and personalised publishing solutions is constantly growing.

Such tools help students take a comprehensive approach to book production: from the scientific analysis of materials to technological design, engineering calculations, graphic design and mathematical modelling of processes. This ensures not only an interdisciplinary approach, but also preparation for real-world professional practice.

3.3 Algorithms for combining technical and technological parameters of printing with the artistic logic of artificial intelligence and the mechanics of immersion.

Creating a modern interactive publication requires a shift away from linear design towards the development of complex multidimensional algorithms, where traditional printing standards are interwoven with the computational logic of artificial intelligence (AI) and the functional mechanics of augmented reality (AR). Within the framework of interdisciplinary course-based design, this synthesis emerges not as a collection of disparate actions, but as a unified technological matrix that ensures the integrity of the user’s perception of the product.

The algorithmisation of such a process involves the harmonisation of three critically important vectors.

1. Technical and technological parameters of printing: these form the foundation, encompassing requirements for resolution, colour gamut (CMYK vs RGB), paper types and finishing methods. In the context of immersivity, these parameters take on new significance: for example, the gloss level of the paper surface is now analysed as a factor affecting the stability of AR marker recognition by a mobile device’s camera.

2. The artistic logic of artificial intelligence: the use of generative models (GenAI) introduces an element of intellectual variability into publication design. Students must master ‘prompt engineering’ algorithms – the process of transforming a

verbal concept into a visual asset, which must correspond to the publication's style and the technical requirements of print reproduction.

3. Mechanics of immersion: developing interaction design scenarios where a physical object (a book) becomes a portal to digital space. Here, the algorithm determines the transition logic: from a visual trigger on the page to the activation of a 3D model, audio track or animation in augmented reality.

The synergy of these components within the STEAM approach enables the creation of an algorithmic sequence of actions: from generating unique content using AI, through its technical adaptation to printing requirements, to its final integration into an immersive environment. This approach transforms the course project from an educational exercise into a full-scale study of 'Smart Edition', where every technical parameter of printing is subordinated to the overall logic of interactive communication.

Examining these algorithms reveals the points of intersection between engineering calculations and creative digital technologies, which is a prerequisite for training competitive specialists in the G20 specialisation 'Publishing and Printing'.

Thus, the methodological aspects of integrating such elements are aimed at creating a comprehensive, practice-oriented educational environment that meets the contemporary challenges of professional activity in the field of publishing and printing.

Research results

1 Basic approaches to combining STEAM elements into an interdisciplinary course project.

For the effective integration of technical, artistic and digital technologies into the learning process during a course project on book production, it is necessary to use specific models, methodologies and technological solutions. Let us consider the main approaches to such integration.

1. Project-based learning model.

Essence: Higher education students work in teams to produce a book, going through all the stages: concept → design → technical calculations → selection of equipment → printing.

Tools:

– Technical tools: AutoCAD, Printflow (for process design);

– Artistic tools: Adobe InDesign, Illustrator (for layout and design);

– Digital tools: AR modelling of the production process, automated cost calculations in Excel.

Result: integration of all aspects into a comprehensive project.

2. STEAM laboratory for publishing technologies.

Essence: establishment of a laboratory combining technical, artistic and digital tools.

Components:

– digital printing technologies: process modelling on digital printing presses (Heidelberg Prinect);

– 3D printing and prototyping: use of 3D modelling to create mock-ups of book covers and die-cuts;

– UX/UI design: development of interactive book layouts for digital publications (Figma, Adobe XD).

FabLabs (short for 'Fabrication Laboratory') are laboratories that specialise in digital fabrication and robotics. Their main components are computer-controlled machines, such as 3D printers, laser cutters, CNC machines, electronics and tools for working with various materials. The significance of FabLabs based at higher education institutions (HEIs) in STEM (Science, Technology, Engineering, Mathematics) and STEAM (STEM plus Art) education can be considerable and has several aspects. [4]

Result: a combination of traditional publishing processes with modern digital approaches.

3. The 'Learning Print Factory' model.

Essence: creating a simulation of real-world printing production.

Stages of work for higher education students:

1. Study of the technological process – examination of printing equipment, calculation of printing parameters.

2. Digital modelling – creation of 3D simulations of printing press operation (SolidWorks, Printflow).

3. Practical implementation – printing and quality control of prints on real equipment.

Outcome: developing an understanding of the actual production cycle and integrating digital technologies into the printing industry.

4. Blended learning model.

Essence: combining face-to-face learning with digital technologies.

Methods: AR simulations of printing processes – modelling the operation of an offset press in AR.

Simulations can teach things that cannot be learnt through lectures or case studies. Here, students are immersed in ambiguous, often contradictory situations that force them to think critically and strategically, make quick decisions and, perhaps most importantly, immediately see the consequences of their actions, and thus learn from their own mistakes rather than those of others. This approach focuses not only on the acquisition of knowledge, but also on the methods of this acquisition, on models and ways of thinking and acting, and on the development of students' cognitive abilities and creative potential as they solve learning tasks specially organised by the teacher. However, it is worth noting that the bulk of the learning process takes place outside the simulation. Therefore, the necessary learning context is crucial to make the experience gained during the game process meaningful. For the simulation to become part of the learner's own experience gained during the learning process, there must be a discussion to resolve the problematic issues that arose during the investigation. [5]

Online platforms for testing technological solutions (Heidelberg Prinect Workflow).

Gamification of the learning process – the use of interactive courses for self-directed study of printing technologies.

Result: a flexible combination of different learning formats.

5. Interactive map of the technological process.

Essence: the use of interactive platforms to visualise the entire technological process of creating a book publication.

Tools:

– Miro, MindMeister – creating process flowcharts;

– Notion, Trello – project management and coordination of students' work.

Result: improved understanding of interdisciplinary connections.

The use of these approaches will enable the synchronisation of technical, artistic and digital aspects within an interdisciplinary course project, as well as making the learning process practice-oriented and closely aligned with the real-world conditions of the printing and publishing industry.

The updated content of the interdisciplinary course project with integrated elements is presented in Table 2.

Table 2 – Revised structure of the course project

INTRODUCTION (Justification of the relevance of using AI and AR in publishing)
1. RESEARCH AND TECHNOLOGICAL SECTION
1.1. Conceptual Framework: Terminology of Interactive and Immersive Publications (AR, VR, Prompt Engineering)
1.2. Psychological Aspects of Immersive Content Perception: Features of Designing Children's Publications with Augmented Reality Elements
1.3. Methodology for preparing interactive external design: from static covers to AR markers
1.4. Justification for the choice of intellectual and immersive tools: comparison of neural networks (for graphics) and AR platforms (for interactivity)
1.5. Specifics of source data for hybrid publications: tagging of digital content and system requirements for AR
1.6. Selection of printing technology and materials: consideration of the characteristics of AR tag reading (paper gloss, contrast)
2. PRACTICAL AND PROJECT-BASED SECTION
2.1. Visual communication concept: combining original design with AI-generated elements
2.2. Designing an immersive scenario: developing interactions between the printed page and digital objects
2.3. Generating and processing graphic content using AI: methods for creating illustrations and textures
2.4. Developing a publication's original layout with integrated markers
2.4.1. Technical specifications for layout: parameters for placing AR elements
2.4.2. Additional multimedia layers: preparation of audio, video or 3D content
2.5. Creation of interactive presentation material: demonstration of the publication via a mobile app or virtual preview
CONCLUSIONS

This updated syllabus enables the optimal integration of STEAM elements into the course project, focusing on digital technologies, process automation, an interdisciplinary approach and innovations in publishing.

2 Justification of quality criteria for an interactive course project: from technical excellence to an immersive user experience.

The shift towards producing intelligent and immersive publications as part of the course-based design projects undertaken by third-year students on the G20 'Publishing and Printing' programme at the first (bachelor's) level of higher education highlights the need to develop valid criteria for assessing learning outcomes. The traditional assessment system, focused primarily on printing technical regulations and typesetting standards, proves insufficient for analysing products containing elements of artificial intelligence (AI) and augmented reality (AR). A modern course project should be assessed as a comprehensive ecosystem, where the technical quality of the printing process is inseparable from the depth of the user experience (UX). This requires the establishment of a multi-level system of criteria covering both the physical and virtual parameters of the created object.

System of comprehensive evaluation criteria

To ensure the objectivity of the assessment of STEAM integration effectiveness, it is proposed to divide the criteria into three main groups:

1. Technological excellence and print quality.

This is the basic level confirming the professional competence of a future printing specialist:

– Compliance with pre-press standards: correct colour profiles, resolution of illustrations (particularly those generated by AI), and accurate bleed settings;

– Technological compatibility with AR: the ability of the chosen paper and printing method to ensure the stable operation of immersive markers (absence of critical glare, adherence to contrast levels for camera reading);

– Quality of AI content reproduction: absence of generation artefacts that may arise when scaling images for large-format printing.

2. Intellectual and creative level (AI integration).

The student's ability to work with artificial intelligence tools within the STEAM paradigm is assessed:

– Complexity and precision of prompt engineering: the assessment focuses not merely on the presence of a generated image, but on the quality of the author's prompt, which enabled the achievement of the specified artistic concept;

– Stylistic coherence: how harmoniously AI elements are integrated into the overall design layout of the publication;

– Ethics and copyright: the correct labelling of AI content and justification of its use within the project.

3. Immersive performance and UX design.

The highest level of assessment, determining the success of user interaction with the product:

– Stability of the immersive layer: speed of AR content activation, absence of 'shaking' of objects in virtual space, and the logic of transitions between pages and screens;

– Cognitive accessibility (Usability): intuitiveness of the user interface (is it clear where exactly on the page the interactive element is hidden);

– Value of the immersive experience: does augmented reality add new meaning to the publication, or is it merely a decorative element.

Integrated Assessment Methodology

To summarise the results, it is proposed to use a competency matrix, where each group of criteria has its own weighting factor. This allows the assessment to be differentiated depending on the complexity of the task at hand:

– If the project focuses on children's literature, the criterion of immersive effectiveness (game mechanics) carries greater weight;

– If it is a technical publication, priority is given to technological excellence and the accuracy of visualisation.

Justifying these criteria allows lecturers not only to measure the performance of individual students, but also to analyse the effectiveness of the entire STEAM methodology in the third-year curriculum. This creates reliable feedback for the subsequent adjustment of the content of educational components for third-year students of the G20 specialisation 'Publishing and Printing' at the first (bachelor's) level of higher education.

3 Research into the impact of AI-integrated STEAM methodology on the development of professional and soft skills among higher education students.

The integration of artificial intelligence and immersive technologies within the STEAM approach to course design is transforming not only the technological cycle of publishing but also the professional profile of higher education students. In today's environment, the G20 specialism 'Publishing and Printing' requires graduates to combine technical expertise (hard skills) with versatile personal qualities (soft skills), enabling them to work effectively in a highly dynamic technological environment. Research into the impact of such a methodology on the development of third-year students' skills allows for an assessment of the pedagogical effectiveness of these innovations and determines the level of readiness of future specialists to meet the challenges of the digital economy.

Transformation of professional skills (Hard Skills).

The integration of AI and AR into educational design expands the traditional set of professional competencies, transforming them into "hybrid skills".

1. Prompt engineering and visual literacy: The student masters the skill of algorithmic control of neural networks, which requires a clear understanding of composition, color, and technical parameters of the image (DPI, file format, color model).

2. Designing the architecture of immersive interaction: The skill of creating logical connections between physical and digital objects. This requires basic knowledge of programming (scripting in AR applications) and spatial thinking.

3. Technological audit of innovations: The ability to critically assess the quality of content created by AI and its suitability for printing according to state standards (DSTU).

Development of “soft” skills in the context of STEAM.

STEAM methodology, based on the creation of an interactive product, becomes a powerful catalyst for the development of supra-professional skills:

– Critical thinking and analysis: Working with AI teaches the student not to accept the first result obtained, but to analyze it for errors ("hallucinations" of AI), technical defects and aesthetic compliance;

– Adaptability and flexibility (Agility): The rapid change of versions of neural networks and AR platforms teaches applicants to lifelong learning. A 3rd-year student becomes able to quickly master new interfaces, which is a key challenge of our time;

– Creativity and solving complex problems (Problem Solving): Creating an immersive publication is always a challenge that requires non-standard solutions (how to make an AR label readable on a curved book spine or in low light);

– Cognitive empathy: When developing UX design for an immersive product, the student is forced to “put themselves in the user’s shoes,” which develops emotional intelligence and understanding of the audience’s needs.

The following methods can be used to analyze learning outcomes and the impact of STEAM methodology on higher education students.

1. Survey of higher education students:

– Collecting feedback on their experience working on the project;

– Assessing the level of satisfaction with the use of STEAM elements.

2. Comparative analysis of results:

– Comparing the results of students who worked using the traditional methodology with those who used the STEAM approach;

– Assessing the level of creativity, quality of task performance, and practical value of projects.

3. Expert assessment:

– Involving specialists from the publishing and printing industry to assess the quality of the developed projects;

– Analysis of expert feedback on the innovativeness and suitability of projects for implementation.

4. Quantitative and qualitative indicators:

– Assessment of student success using a grading system;

– Analysis of the number of successfully defended projects.

Results of the analysis:

– Increasing the level of interest of higher education students in learning;

– Improving the quality of project implementation through the integration of STEAM elements;

– Developing critical thinking, creativity, and teamwork skills among higher education students.

4 Comprehensive assessment of the effectiveness of implementing innovative technologies in instructional design.

The effectiveness of implementing AI-integrated STEAM methodology in the process of interdisciplinary course design cannot be measured only by traditional academic performance indicators. The specificity of the design object – an interactive publishing product with elements of artificial intelligence and immersiveness – requires the development of a multi-vector monitoring system. Such a system should be based on the principle of scientific objectivity and cover three key levels of assessment: internal-academic (expert), subjective-reflective (student) and external-industrial (stakeholder).

A comprehensive approach to performance assessment allows solving a number of critical tasks.

1. Verification of professional competencies: determining the level of mastery of technical and technological parameters of printing production in synergy with new digital tools.

2. Analysis of the educational experience of applicants: a study of students' satisfaction with innovative teaching methods, which is a direct indicator of their motivation and involvement.

3. Validation of innovative potential: checking the compliance of the created projects with the current demands of the modern media market and the requirements of the digitalization of the industry.

Within the framework of this study, a departure from the "teacher as a single controller" model is proposed in favor of the "multilateral quality audit" model. This allows not only to set a final grade for the course project, but also to obtain in-depth data for correcting the entire STEAM strategy for training higher education applicants of the first (bachelor's) level of the 3rd year of the G20 specialty "Publishing and Printing".

The criteria and mechanisms of interaction of all participants in the evaluation process are detailed below, which provides a holistic view of the effectiveness of the implemented innovations in the context of modern technological challenges.

Criteria and mechanisms of interaction of all participants in the evaluation process.

I. Interaction "Teacher - Applicant": Expert and technological audit.

This is the basic level, where the teacher acts as a professional expert who evaluates Hard Skills and the project's compliance with industry standards.

Evaluation criteria:

– Technological validity: correctness of preparation of files for printing (issues, overprints, resolution of AI illustrations);

– Immersive communication stability: speed and accuracy of AR marker operation on different types of paper;

– Algorithmic literacy: assessment of "prompt engineering" (how consciously the student controlled AI to achieve the result);

– Interaction mechanism: Portfolio protection: the student demonstrates the "live" interaction of the printed edition and the mobile application.

Technology review: joint analysis of errors in color profiles or 3D models.

At the "Teacher – Student" level, the assessment focuses on objective quality indicators (Hard Skills) and the student's ability to justify their technological solutions. This is a fundamental stage, since it is here that compliance with DSTU and ISO industry standards is checked in synergy with innovations.

The teacher acts as the chief technologist/art director, who checks the project for "viability" in production conditions. It is advisable to conduct the assessment according to four key descriptors.

1. Technological audit of prepress processes (Prepress Quality):

– Correctness of AI content: Checking the generated illustrations for the absence of visual artifacts, noise and compliance with the resolution (300 dpi);

– Color authenticity: Accuracy of conversion from RGB (AI and AR models) to CMYK (printing). Absence of "dropping" of colors into out-of-gamut areas;

– Technical layout: Correctness of setting of bleeds, safe zones, overprints and trapping.

2. Assessment of the intellectual component (AI-literacy):

– Quality of prompt engineering: The teacher analyzes the "prompt journal" (appendix to the project). The student's ability to use specific parameters (style, lighting, angle) to achieve a holistic artistic result is assessed;

– Stylistic integrity: The extent to which the generated elements harmonize with the text block and the overall grid of the publication.

3. Immersive Stability Audit (AR-Functionality):

– Marker Efficiency: Checking the contrast and detail of printed areas that are triggers for AR. Assessing how the choice of paper (matte/glossy) affects reading;

– Interaction Logic: The "immersive scenario" is assessed – whether the appearance of a 3D model or video is justified and understandable to the user.

4. Justification of the choice of materials (Engineering & Science)

Material science approach: The student must prove why this type of paper and the method of binding were chosen for the publication with AR (for example, so that the spread opens as flat as possible for stable camera focus).

Forms of assessment

For an objective audit, the teacher uses the following methods.

1. Criteria matrix (Rubricator): A table where each parameter (from 1 to 10) corresponds to a clear description of the quality.

2. Live testing: A public demonstration of the project, where the teacher personally tests the AR application on a printed copy (or color proof).

3. Technical interview: A short defense, where the student explains how he resolved a technical conflict (for example, how he improved image quality after AI generation).

An example of a rating scale (fragment) is given in Table 3.

Table 3 – Example of a rating scale (fragment)

Criterion	High level (9-10)	Medium level (7-8)	Low level (1-6)
AI Asset Quality	Illustrations without defects, uniform style, high detail	A few artifacts, style somewhat blurry	Low resolution, obvious generation errors
AR Stability	Instant reading, object "attached" to the page firmly	Reading from attempts, slight "shaking" of the model	Marker not recognized or model constantly disappears

The teacher's expert audit guarantees that the student did not just "play with technologies", but mastered them as professional tools, ready for real production. This ensures strict compliance of the STEAM project with the standards of the G20 specialty "Publishing and Printing".

II. Interaction "Applicant – Educational Environment": Reflective monitoring.

At this level, the applicant evaluates his own development trajectory, which allows measuring the growth of Soft Skills.

Assessment criteria:

– Level of professional autonomy: the ability to independently resolve technical conflicts between AR software and layout;

– Creative confidence: subjective feeling of the ability to create a competitive product;

– Cognitive flexibility: the speed of adaptation to updates of AI tools during the project;

– Interaction mechanism: Self-reflection report: a short essay or questionnaire (which we discussed earlier), where the student analyzes his difficulties and achievements.

Peer-review: mutual testing of AR applications by classmates to assess the usability of the interface (UX).

An important component of monitoring is the subjective assessment of applicants, implemented through the questionnaire-reflection method. This allows us to identify not only the level of knowledge acquisition, but also the dynamics of the applicant's professional self-identification. For example, analyzing the answers to Block 3 (Soft Skills) allows us to track the transition from reproductive to productive thinking, which is a key indicator of the success of STEAM education.

The cycle of reflective learning (Kolb Cycle) Fig. 1 is a classic model that explains how an applicant converts practical experience (creating a course with AI and AR) into knowledge. It consists of four stages that go in a circle:

– Concrete experience: Directly implementing the project (working with neural networks, layout);

– Reflective observation: Understanding what has been done (this is where your reflection survey comes into play);

– Abstract conceptualization: Forming new conclusions and theoretical knowledge (understanding how AI interacts with printing);

– Active experimentation: Applying the knowledge gained in subsequent tasks or real work.

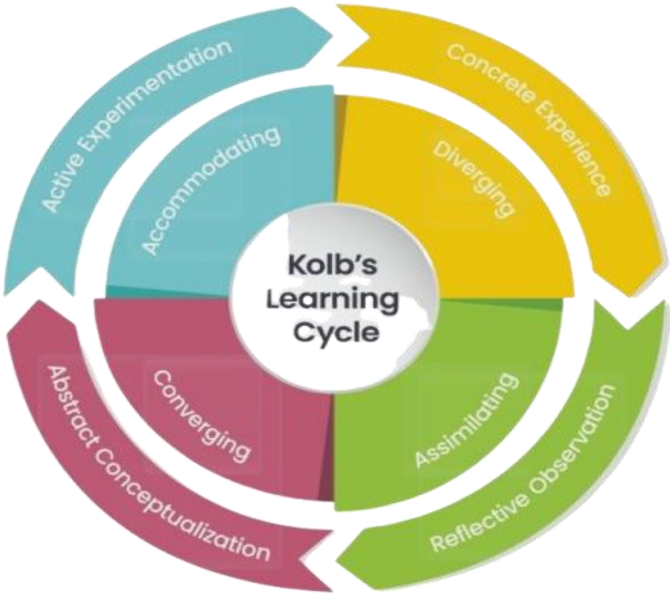

Figure 1 – Reflective Learning Cycle (Kolb Cycle)

III. Interaction "Educational Institution – Industry": Validation of Marketability.

This level ensures that the project meets modern "technological challenges" through the eyes of external stakeholders (employers).

Evaluation criteria:

– Commercial attractiveness: is there a potential demand for this type of multimedia publication;

– Production realism: is it possible to scale this project in real printing houses with existing equipment;

– Innovation potential: does the product meet the trends of Industry 4.0;

– Interaction mechanism: Public Demo Day: presentation of the best projects to representatives of printing houses and IT companies.

Expert feedback list: receiving feedback from industry practitioners on the relevance of the selected AI tools.

The interaction matrix is presented in Table 4.

Table 4 – Interaction matrix

Participant	Role in the process	Object of evaluation	Tool
Teacher	Controller-expert	Technological quality and STEAM logic	Criteria evaluation matrix
Applicant	Active subject	Own experience and Soft Skills	Reflection questionnaire, UX testing
Stakeholder	Customer-validator	Market relevance and innovation	Expert feedback, Demo session

This three-level model ensures integrity, as it closes the loop: from theory (teacher) to practice (student) and to the real market (industry). This guarantees that the implemented innovations will not remain "artificial", but will become a real professional base for the future specialist.

Interaction with external stakeholders (representatives of printing houses, publishers, IT companies) allows you to verify the results of STEAM design through the prism of real market demands. Assessment at this level focuses on three vectors: technological realism, economic feasibility and innovative competitiveness.

Evaluation criteria from industry representatives.

1. Scalability:

– Is the layout suitable for printing on standard equipment (offset/digital)?

– How complex and expensive is the post-printing processing to activate immersive properties (use of varnishes, specific types of paper)?

2. Quality of consumer experience (Market UX):

– How intuitive is the combination of "book + app" for the average buyer?

– Does AR content carry added value that would make the client buy this publication more expensive than the usual one?

3. Technological relevance of the stack (Tech Stack Relevance):

– Do the AI tools and AR platforms chosen by the applicant correspond to those actually used in modern media holdings?

– Assessment of the "purity" of licenses and copyrights for the generated content.

Example of questions for an expert (stakeholder).

1. Are you ready to implement such technology (AI-illustration + AR) in your company?

2. What is the probability that this project will be commercially successful on bookstore shelves (from 1 to 10)?

3. Assess the student's level of training: does he have enough knowledge to work as an "innovative publishing technologist"?

To obtain objective data, it is recommended to use the tools presented in table 5.

Table 5 – Mechanisms and forms of assessment

Evaluation Form	The essence of the mechanism	Monograph output
Review Card	Questionnaire for an industry specialist with short questions about the quality of the project	Statistical indicator of "market readiness"
Demo Day / Pitching	Student presents the project as a startup to the employer council	Assessment of communication skills and the ability to "sell" an idea
Blind Testing	Professional technologists test AR markers without student prompts	Verification of the technical stability of the product
Industry Feedback Session	Roundtable where employers analyze errors in the logic of immersive publishing	Qualitative conclusions for improving the training program

Involving industry representatives in evaluating course projects creates a “feedback” effect. This allows the educational institution to quickly adjust the STEAM methodology in accordance with how the market changes (for example, the transition from one AR engine to another), ensuring the training of specialists who do not require retraining after graduation.

Conclusions

Analysis of learning outcomes using AI-integrated STEAM methodology allows us to assert that applicants demonstrate a higher level of engagement compared to traditional design methods.

The use of artificial intelligence and immersive tools in the course project removes the psychological barrier of "fear of a blank slate" and allows you to focus on the strategic vision of the product.

Thus, the STEAM methodology does not just teach the student to use new programs, but forms an innovative type of thinking. The graduate becomes not just a technical performer, but a creative leader, able to design complex media systems that combine machine intelligence and the emotionality of human art. This is the ultimate goal of modernization of higher education in the context of modern global challenges.

Based on the conducted research and the obtained results, strategic vectors for the development of the methodology for integrating AI and AR/VR tools into the educational process were identified:

1. Technological expansion and intellectualization of the STEAM component:

– Systematic implementation of generative artificial intelligence models to automate pre-print processes and creative design.

– Integration of mixed reality (MR) technologies to create hybrid publishing products with a high level of interactivity.

2. Modernization of digital and material and technical infrastructure:

– Ensuring access of applicants to high-performance computing power and cloud services for training neural networks.

3. Transformation of the teacher's professional profile:

– Implementation of continuous professional development programs in the field of AI literacy and the development of immersive environments.

4. New generation educational and methodological support:

– Development of dynamic interactive manuals and online platforms, which themselves are based on the principles of immersiveness and AI support.

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