Project Number: 2024-2-LV01-KA210-VET-000280127
Erasmus+ Maza mēroga partnerības projekts "Vadības un administrēšanas jomas profesionālo izglītības programmu pilnveide, ieviešot un pielietojot mākslīgā intelekta, digitālo resursu rīkus un to alternatīvas mācību procesā".
Project No. 2024-2-LV01-KA210-VET 000280127, Improvement of vocational education programmes in management and administration by introducing and applying artificial intelligence, digital resource tools, and their alternatives in the learning process.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or The State Education Development Agency (hereinafter – VIAA). Neither the European Union nor the granting authority (VIAA) can be held responsible for them.
Finansē Eiropas Savienība. Tomēr paustie uzskati un viedokļi ir tikai autora(-u) uzskati un viedokļi un ne vienmēr atspoguļo Eiropas Savienības vai Valsts izglītības attīstības aģentūras (VIAA) uzskatus un viedokļus. Ne Eiropas Savienību, ne piešķīrēju iestādi (VIAA) nevar saukt pie atbildības par tiem.

AUTHOR: SANDRA TETERE[1]

DEVELOPING TECHNOLOGICAL COMPETENCIES IN INTERNATIONAL HIGHER EDUCATION THROUGH TECHNOLOGY-ENHANCED AND MULTIMODAL LEARNING

ABSTRACT

The paper examines technological competency development in higher education, highlighting structured technology-enhanced and multimodal learning as preparation for professional practice in the future digital labour market.

The aim of the study is to examine how a structured technology-based learning approach and the integration of multiple learning modalities influence students' technological competency development, focusing on the balance between theoretical knowledge and practical skills.

An exploratory mixed-methods approach was applied, grounded in the CLIL framework, multimodal learning principles, and the concept of technological competencies,

[1] mg. sc., Alberta College.

with reference to DigComp 3.0. The results show that a structured technology-enhanced learning approach primarily supports students' theoretical knowledge development, while its impact on practical skills is more limited, providing a basis for the future digital labour market.

INTRODUCTION

Rapid technological development and processes of digital transformation significantly affect the environment of higher professional education, highlighting the need for purposeful and systematic development of students' technological competencies[2] as a prerequisite for successful professional activity in a digitally transformed labour market. In the international academic environment, where multilingual and culturally diverse student groups are increasingly common, the use of technology in the learning process becomes not only a support tool but also an essential component of learning content.[3] Under these conditions, higher professional education institutions are required to seek academically and methodologically grounded solutions that simultaneously promote the acquisition of theoretical knowledge and the development of practical skills in line with changing labour market requirements.

In contemporary academic discourse, increasing attention is given to technology-enhanced and multimodal learning approaches, which allow the learning process to be adapted to diverse learning needs[4] and experiences and support students' readiness for professional practice in technology-rich environments.

Such an approach involves the deliberate integration of digital tools as well as visual, auditory, and kinesthetic elements into the learning process, creating a structured and purposeful learning environment. At the same time, in international higher professional education, content and language integrated learning (Content and Language Integrated Learning – CLIL) plays a significant role in supporting academic content acquisition while simultaneously developing students' language competencies[5] as an essential component of professional integration into the international labour market.

Despite the wide availability of technologies and the growing interest in digital solutions in education, research indicates that the integration of technology into the learning

[2] OECD, *Education in the Digital Age: Challenges and Opportunities*, OECD Publishing, Paris 2020, p. 15–18.
[3] European Commission, *Digital Education Action Plan 2021–2027*, Publications Office of the European Union, Luxembourg 2020, p. 6–9.
[4] R. E. Mayer, *Multimedia Learning*, 2nd ed., Cambridge University Press, Cambridge 2009, p. 3–10.
[5] D. Coyle, P. Hood, D.Marsh, *CLIL: Content and Language Integrated Learning*, Cambridge University Press, Cambridge 2010, p. 1–12.

process often fails to ensure a balanced development of theoretical and practical competencies, creating a gap between the acquisition of academic knowledge and its practical application[6] also in professional practice. It is often observed that technology-enhanced learning approaches have a stronger impact on the acquisition of theoretical knowledge, whereas the development of practical skills requires additional methodological solutions and more targeted instructional design. The relevance of these challenges is further reinforced by the latest version of the European Digital Competence Framework, DigComp 3.0, which, unlike the previous DigComp 2.2 version, emphasises not only the acquisition of digital skills but also the development of adaptability to rapid digital change and digital resilience[7] as a key prerequisite for sustainable employability.

This paper is based on the results of the author's previous research, obtained through the analysis of the implementation of technology-enhanced and multimodal learning approaches in an international higher professional education context, involving students from diverse linguistic and academic backgrounds. The paper has also been developed within the framework of the Erasmus+ Small-scale Partnership project KA210-VET (Project No. 2024-2-LV01-KA210-VET-000280127), which aims to enhance vocational and higher education programmes through the introduction of digital solutions and technology-enhanced learning approaches in an international context. Thus, the study provides analytical insight into the development of technological competencies in higher professional education, with a direct link to labour market requirements, while also serving as an intermediate project outcome.

The paper aims to contribute to the discussion on effective strategies for technology integration in higher professional education and to outline directions for future research, particularly focusing on more effective development of practical technological skills to strengthen students' professional competitiveness in a digitally transformed labour market.

1. PURPOSE OF THE RESEARCH

The aim of the research is to analyse how a consciously and purposefully structured technology-enhanced and multimodal learning approach influences the development of students' technological competencies in an international higher professional education

[6] A. Kirkwood, L. Price, *Technology-enhanced learning and teaching in higher education: what is "enhanced" and how do we know?*, „Learning, Media and Technology" 2014, 39(1), p. 6–36.
[7] European Commission, *DigComp 3.0: The Digital Competence Framework for Citizens*, Publications Office of the European Union, Luxembourg 2023, p. 5–12

environment, with particular attention to the balance between the development of theoretical knowledge and practical skills.

The study seeks to answer the question of how such a learning approach affects the balance between theoretical knowledge and practical skill development in the field of technology, in response to the need to foster adaptability and digital resilience emphasised in DigComp 3.0.

2. MATERIALS AND METHODS

The study involved 56 higher professional education students in Riga, Latvia, who attended a study course in product development during the spring semester of the 2024/2025 academic year. All participants were full-time students with no significant prior professional work experience in the relevant field. The composition of the student groups remained unchanged throughout the study; the control and experimental group status was assigned to existing groups at random.

In the experimental group, the learning process was organised using a technology-enhanced and multimodal learning approach. The learning intervention integrated the CLIL approach (Content and Language Integrated Learning), ensuring the simultaneous acquisition of subject-specific content and a professional foreign language. Learning tasks were structured in stages, gradually increasing their level of complexity and ensuring repeated reinforcement of learning content through different formats.

The learning intervention was designed using a technology-enhanced and multimodal approach, integrating CLIL to support simultaneous subject content and professional language acquisition. Learning activities were structured progressively and delivered through multiple modalities, informed by VAK and VARK learning style models, to ensure accessibility, reinforcement of learning content, and engagement of students with diverse learning preferences.

The learning process employed digital tools and online platforms, interactive and visual materials, and practical tasks aimed at developing technological competencies in the context of product development. To support interactivity, online knowledge-assessment and reinforcement tasks (e.g., interactive tests) were also used, serving both formative assessment purposes and the promotion of student self-assessment. These tasks enabled prompt feedback and repeated reinforcement of the learning content.

In the control group, the study course was implemented according to the standard study organisation, without the structured integration of a purposefully technology-enhanced and multimodal approach.

Data collection included academic results obtained within the study course prior to the start of the experiment. The average results of previous assessment tasks were used to verify the initial comparability of the control and experimental groups before the learning intervention.

During and after the implementation of the learning intervention, both assessment task results and final examination results were analysed in order to reduce the potential influence of a single assessment element on the research outcomes and to ensure a more comprehensive evaluation of students' learning achievements. In addition, the results of students' completed tasks and the instructor's observations during the learning process were analysed to obtain a multifaceted understanding of students' learning progress.The collected data were analysed using descriptive statistical methods, calculating mean values (AVG) and standard deviation (SD). To provide an indicative assessment of group comparability at the beginning of the study, Welch's independent samples t-test was additionally applied. Given the small sample size, inferential statistical results were interpreted with caution, with primary emphasis placed on trends in learning outcome changes rather than on the identification of statistically significant differences.

3. RESULTS

To compare the baseline knowledge level between the control group and the experimental group, descriptive statistical analysis was conducted, and Welch's independent samples t-test was applied for demonstrative purposes. The aim of these calculations was to obtain an indicative assessment of group comparability at the beginning of the study, while acknowledging the small sample size and the associated limitations of inferential statistics.

Descriptive statistics show that the mean performance of the control group in previous course assessment tasks prior to the experiment was 68.22%, whereas the mean performance of the experimental group was 58.65%. The standard deviation (SD) was similar in both groups (SD = 4.82 in the control group and SD = 4.70 in the experimental group), indicating comparable result dispersion and internal group homogeneity.

Welch's t-test indicated no statistically significant difference between group means ($t = 2.01$; $p = 0.18$), suggesting comparable baseline knowledge levels. Given the small sample size, subsequent analysis focused on descriptive trends rather than inferential significance.

Accordingly, subsequent analysis focused on mean values and trends in learning outcomes rather than statistical significance, as the small differences between groups (below 1%) indicate comparable baseline knowledge levels and allow observed changes to be interpreted in relation to the learning intervention.

Table 1. Comparison of baseline knowledge levels between the control and experimental groups

Indicator/ Group	Subgroups (n)	Participants (N)	Mean (%)	SD	t	p
Control group	2	29	68.22	4.82		
Experimental group	2	27	58.65	4.70		
Between-group comparison					2.01	0.18

Note. n refers to the number of student subgroups within each group, while N refers to the number of participants. Students in each group were divided into two subgroups with a similar number of participants. Calculations were based on subgroup mean values. t – Welch's t-test statistic; p – p value. Due to the small number of subgroups, inferential statistical results should be interpreted with caution and used as supplementary information to characterise group comparability.

Impact of the learning intervention on the development of theoretical knowledge and practical skills

This subsection analyses the impact of the learning intervention on the development of students' theoretical knowledge and practical skills within the product development study course. Learning outcomes were assessed by analysing results from assessment tasks and interactive tests conducted during the learning process, as well as final examination results obtained after the implementation of the learning intervention.

The analysis was carried out by comparing learning outcomes of the control and experimental groups, while subgroup data were used to calculate mean values. Interactive test results were analysed descriptively, focusing on trends in performance changes rather than tabulated summaries.

The dynamics of theoretical knowledge acquisition were analysed based on the results of interactive tests conducted in three consecutive attempts during the learning intervention. During the pilot implementation of interactive tests, a high level of student engagement was observed, which may be associated with the integration of digital technologies into the learning process and learning characteristics typical of the student cohort.

Results from the first attempt indicate that the initial performance of the control and experimental groups was comparable, with differences not exceeding 1%, suggesting a similar baseline knowledge level.

Already in the second attempt, substantial differences between the groups emerged. In the experimental group, performance increased from 28% to 60%, whereas in the control group it increased from 27% to 42%. Although progress was observed in both groups, the rate of theoretical knowledge development was considerably faster in the experimental group.

A similar trend was observed in the third attempt, where the experimental group achieved 88% correct responses, while the control group's performance increased to 46%. These results indicate a more pronounced consolidation of theoretical knowledge in the group in which the CLIL approach and elements of multimodal learning strategies were purposefully integrated into the learning process.

To evaluate final outcomes in theoretical knowledge acquisition, examination results were also analysed. The examination was designed in accordance with the study course objectives and intended learning outcomes, ensuring a consistent assessment approach and comparable results across both groups. Analysis shows that the mean examination score of the control group was 73.54%, whereas the experimental group achieved a mean score of 77.40%, representing a difference of 3.86 percentage points in favour of the experimental group.

Descriptive statistics indicate that result dispersion in the control group was relatively low (SD = 1.54), while greater variability was observed in the experimental group (SD = 3.18). Welch's independent samples t-test shows that the observed difference between group means is not statistically significant ($t = 1.54$; $p = 0.31$), which can be attributed to the small number of analytical units. Consequently, these results should be interpreted with caution, with primary emphasis placed on trends in learning outcome changes.

The development of practical skills was assessed based on the results of creative examination tasks, which focused on students' ability to apply acquired knowledge in new situations, such as designing a new system or product. Examination tasks were structured across three levels of difficulty:

(1) knowledge recall corresponding to a surface learning level;

(2) application of knowledge and analytical thinking;

(3) creative tasks demonstrating knowledge application in new situations.

This structure ensured a combined assessment reflecting both theoretical knowledge levels and elements of practical skills.

It should be noted that, due to data-recording limitations, the researcher was unable to separately analyse the results of individual examination tasks; only overall examination results were available. However, information on task types and their alignment with the three difficulty levels enabled a qualitative interpretation of the nature of practical skill development.

Analysis of the results shows that the difference between the control and experimental group performance in the examination was less pronounced than differences observed in theoretical knowledge assessments during the learning process. This finding should not be interpreted as an ineffectiveness of the learning intervention, but rather as an indication of differing dynamics in the development of theoretical knowledge and practical skills.

The results suggest that the applied learning intervention—CLIL and multimodal learning strategies—has the strongest impact on theoretical knowledge acquisition, whereas the development of practical skills requires a longer-term and more targeted didactic approach.

For the comprehensive development of practical skills, additional instructional solutions are required, such as demonstrations, experimental activities, project-based learning, and extended practical engagement cycles. This highlights the need for future research to place particular emphasis on methods for developing practical skills in higher professional education, especially in technology-enhanced learning environments.

4. DISCUSSION

In this section, the research findings are interpreted by relating them to the research aim, the theoretical framework, and current research insights on technology-enhanced and multimodal learning in higher professional education. The discussion is based on a comparison of learning outcomes between the control group and the experimental group, with particular

attention paid to the differing dynamics of theoretical knowledge and practical skill development.

The results of the study confirm that the learning intervention grounded in the CLIL approach and multimodal learning strategies had the most pronounced impact on the acquisition of theoretical knowledge. This effect is demonstrated by both the rapid improvement observed in interactive test results and the higher mean examination scores achieved by the experimental group. These findings are consistent with R. E. Mayer's theory of multimodal learning, which emphasises that presenting information in multiple, complementary formats promotes deeper cognitive processing and more effective structuring of theoretical content.[8] A similar explanation is provided by A. Paivio's dual coding theory, which highlights the importance of the parallel processing of verbal and visual information in concept integration and memory processes.[9]

The interpretation of the results is also significantly influenced by the structure of the examination and the specifics of data recording. The examination included tasks at three levels of difficulty—knowledge recall, knowledge application, and creative tasks—thus providing a combined assessment of theoretical knowledge and elements of practical skills. [10]However, the development of practical skills was analysed based on overall examination results and task types rather than on detailed quantitative indicators for each individual task. [11]This limitation restricts the ability to precisely distinguish the development of different skill levels, while simultaneously highlighting the need for future studies to further refine assessment and data analysis approaches.

The importance of technology-enhanced learning environments in educational processes is also emphasised in international policy and research contexts. The Organisation for Economic Co-operation and Development (OECD) notes that the use of digital tools has a positive impact on learning outcomes only when they are integrated purposefully and in alignment with pedagogical objectives.[12]

[8] R. E. Mayer, *Multimedia Learning*, Cambridge University Press, Cambridge 2009, p. 47.
[9] A. Paivio, *Dual Coding Theory: Retrospect and Current Status, "*Canadian Journal of Psychology" *1991*, 45(3), p. 255–287.
[10] A. Rahmanu, G. Molnár, *Multimodal pedagogy in higher education: A systematic review*, "Heliyon" 2024, 10(4), p. 9-11.
[11] R. Safinas, R.Harun, A. Kaur, J.Singh, *Multimodal learning in higher education: A systematic review.* [in:] *Innovations in Educational Technology*, ed. M. M. Asad et al., Taylor & Francis, London 2024, p.288-290.
[12] OECD, *Digital Education Outlook 2021: Pushing the Frontiers with Artificial Intelligence, Blockchain and Robots*, OECD Publishing, Paris 2021, p. 95-96.

This insight is consistent with the approach implemented in the study, in which technological solutions were used as instructional support tools for structuring and reinforcing content rather than as an end in themselves.

At the same time, the study results indicate that the impact of the learning intervention on the development of practical skills was less pronounced than its effect on theoretical knowledge acquisition. This difference can be explained by the specific nature of practical skill development. D. Kolb's experiential learning theory emphasises that the development of practical skills requires repeated experiential cycles involving action, reflection, conceptualisation, and the testing of new actions.[13] More recent studies on CLIL and technology integration in higher education also indicate that the development of practical skills requires sustained, authentic, and project-based learning rather than short-term instructional interventions.[14]

The high level of student engagement observed during interactive tests may be associated with the use of digital technologies and contemporary students' learning habits. However, the obtained results should not be interpreted solely as a short-term motivational or visual memory effect. Examination results, which assessed different cognitive levels, indicate that the impact of the learning intervention also contributed to more sustained acquisition of theoretical knowledge. This interpretation aligns with the European Commission's Digital Competence Framework (DigComp), which emphasises that digital competence encompasses not only the acquisition of technical skills but also the ability to adapt to digital change and to develop digital resilience.[15] [16]

From a labour market perspective, the results highlight the importance of purposefully structured learning approaches that support not only knowledge acquisition but also students' preparedness for professional practice in a digitally transformed work environment. By fostering technological competencies aligned with adaptability and digital resilience, such approaches contribute to graduates' employability and their capacity to respond to evolving labour market demands, thereby reinforcing the role of higher professional education in preparing students for sustainable participation in the future digital labour market.

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[13] D.A.Kolb, *Experiential Learning: Experience as the Source of Learning and Development*, Prentice Hall, 1984, p. 20-28.

[14] Y. Huang, H. Chen, C.Wu, *Technology-enhanced CLIL in higher education: Effects on content and language learning*, "Educational Technology Research and Development" *2023*, 71, p. 1235–1254.

[15] European Commission, *DigComp 2.2: The Digital Competence Framework for Citizens*, Publications Office of the European Union, Luxembourg 2022, p. 2-7.

[16] European Commission, *DigComp 3.0*, op. cit., p. 9–13.

CONCLUSIONS

The aim of this study was examine how a structured technology-based learning approach and the integration of multiple learning modalities influence students' technological competency development, focusing on the balance between theoretical knowledge and practical skills. Based on the empirical data obtained, several conclusions can be drawn.

The findings indicate that the learning intervention, in which digital tools and multimodal strategies were integrated in a deliberate and systematic manner, facilitated faster acquisition of theoretical knowledge in the experimental group compared to the control group. At the same time, it was found that the impact of the intervention on the development of practical skills was less pronounced, pointing to the need to employ additional, practice-based didactic methods to support the enhancement of practical competencies.

The results also confirm that the use of technology in the learning process alone does not guarantee consistent improvement in student learning outcomes across all learning dimensions. Positive effects were observed when digital tools and multimodal strategies were applied purposefully and aligned with specific learning objectives, particularly in the acquisition of theoretical knowledge.

The learning style models applied in the study (VAK and VARK) served as a methodological foundation for the implementation of the multimodal approach, ensuring the presentation of learning content through multiple modes of representation; however, they were not analysed as separate comparable factors influencing student learning outcomes.

Overall, the study provides an empirical contribution to the discussion on the use of technology-enhanced and multimodal CLIL approaches in student learning within higher professional education by clarifying their potential and limitations. The conclusions may serve as a basis for the further development of study courses as well as for future research on the integration of theoretical knowledge and practical skills.

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ROZWÓJ KOMPETENCJI TECHNOLOGICZNYCH W MIĘDZYNARODOWEJ EDUKACJI WYŻSZEJ POPRZEZ NAUCZANIE WZBOGACONE TECHNOLOGIĄ I WIELOMODALNE

STRESZCZENIE

Artykuł analizuje rozwój kompetencji technologicznych w szkolnictwie wyższym, podkreślając znaczenie strukturalnego nauczania wzbogaconego technologią oraz nauczania wielomodalnego jako przygotowania do przyszłej praktyki zawodowej na cyfrowym rynku pracy.

Celem badania jest zbadanie, w jaki sposób strukturalne podejście oparte na technologii oraz integracja różnych modalności uczenia się wpływają na rozwój kompetencji technologicznych studentów, ze szczególnym uwzględnieniem równowagi między wiedzą teoretyczną a umiejętnościami praktycznymi.

Zastosowano eksploracyjne podejście mieszane, oparte na ramach CLIL, zasadach nauczania wielomodalnego oraz koncepcji kompetencji technologicznych, w odniesieniu do DigComp 3.0. Wyniki pokazują, że strukturalne nauczanie wzbogacone technologią przede wszystkim wspiera rozwój wiedzy teoretycznej studentów, podczas gdy jego wpływ na umiejętności praktyczne jest bardziej ograniczony, tworząc jednocześnie podstawy do funkcjonowania na przyszłym cyfrowym rynku pracy.