TPACK IN DIDACTIC MODELING IN THE PRACTICAL TRAINING OF STUDENTS IN TECHNOLOGY AND ENTREPRENEURSHIP

Vasilisa Valeova
SWU "Neofit Rilski", Faculty of Engineering, Blagoevgrad, Bulgaria, vasy_pav@swu.bg

Abstract: This article explores the application of the TPACK (Technological Pedagogical Content Knowledge) model in the didactic modeling of practical training for students in the fields of technology and entrepreneurship within a modern digital educational environment. Particular attention is paid to the integration of technological, pedagogical, and content knowledge as a fundamental prerequisite for the effective preparation of future teachers and for the development of sustainable professional competencies aligned with contemporary educational and labor market requirements. The study examines the theoretical foundations of the TPACK framework and analyzes its role as a conceptual and methodological basis for the purposeful design, organization, implementation, and assessment of educational activities with practical, project-oriented, and entrepreneurial focus.

The article emphasizes the importance of digital transformation in education and the need for innovative teaching approaches that combine active learning, interdisciplinary integration, and the use of modern educational technologies. Various didactic solutions are presented that support the formation of creativity, critical thinking, problem-solving abilities, collaboration, and digital literacy among students. The research highlights the possibilities for integrating digital platforms, virtual learning environments, simulations, interactive applications, multimedia resources, and cloud-based technologies into the practical preparation of students in technology and entrepreneurship education.

Special attention is devoted to the design of practical learning tasks and project-based activities connected to real technological and economic challenges, which stimulate entrepreneurial thinking and encourage students to apply theoretical knowledge in authentic contexts. Examples are provided of educational scenarios and models for practical activities developed through the TPACK approach, demonstrating how technological tools can enhance pedagogical effectiveness and improve learner engagement and motivation.

The article also discusses the role of the teacher as a facilitator, mentor, and designer of innovative learning environments capable of adapting to the rapidly changing demands of the digital society. It is argued that the successful implementation of the TPACK model contributes not only to improving the quality and effectiveness of practical training, but also to strengthening students' readiness for professional realization, lifelong learning, and successful adaptation to dynamic socio-economic and technological transformations.

In conclusion, the study confirms the significance of the TPACK model as an effective framework for modernizing technology and entrepreneurship education and for supporting the development of competent, flexible, and digitally prepared future professionals and educators.

Keywords: TPACK, didactic modelling, practical training, technology and entrepreneurship, pedagogical competencies.

1. INTRODUCTION

Higher education functions as a complex learning community in which teachers and students interact in the process of building and developing professional, social and pedagogical competences at the highest level. In the conditions of accelerated digitalization, increasing dynamics and uncertainty in the socio-economic environment, universities are faced with the need to transform traditional models of teaching, assessment and professional training. This is also relevant for the practical training of students, future teachers, which requires a targeted and meaningful integration of subject content, pedagogical approaches and digital technologies. In this context, the educational policies of the European Union are aimed at the modernization and digital transformation of higher education, which are key prerequisites for increasing the quality, inclusiveness and practical applicability of training. The European Education Area has formulated a common strategic vision aimed at developing key competences, promoting lifelong learning and stimulating transnational academic mobility through strategic documents and initiatives such as the European Skills Agenda, the European Qualifications Framework (EQF), the Erasmus+ Program, the Digital Education Action Plan and the European Education Area. In this context, the emphasis is placed on preparing individuals capable of adapting to dynamically changing socio-economic conditions and applying their knowledge in a variety of professional and life situations. At the national level, these trends are reflected in normative and strategic documents such as the Pre-school and School Education Act and Ordinance No. 15 of 2019 on the Status and Professional Development of Teachers, which define the framework for professional competences, pedagogical autonomy and continuous professional development. In this sense, practical training in higher education should be

organized through modern didactic models that support the development of integrated pedagogical thinking and skills for adaptation to the specific educational context.

In accordance with the European Framework for Entrepreneurial Competence - EntreComp, entrepreneurship is considered a key competence that combines creativity, initiative, digital literacy, decision-making skills and the ability to transform ideas into real practical value (European Commission, 2021). This framework goes beyond the traditional understanding of entrepreneurship as an economic activity and establishes it as a transversal competence applicable in all educational and professional fields. These priorities set new requirements for the didactic modeling of the learning process for the preparation of student teachers in Technology and Entrepreneurship, capable of implementing innovative, technologically and pedagogically sound educational solutions. Educators and learners should be able to engage positively, critically and ethically with AI systems. (European Commission, 2022) The integration of artificial intelligence in education requires teachers to develop new forms of technological pedagogical content knowledge related to AI. (Chai et al., 2021)

2. THEORETICAL BASIS OF THE TPACK MODEL

The need for an integrative approach to the planning and implementation of the learning process draws attention to theoretical models that unite the content, pedagogical and technological dimensions of teaching. Such an integrative perspective finds its theoretical justification in the TPACK (Technological Pedagogical Content Knowledge) model, developed by Mishra and Koehler (Mishra & Koehler, 2006). The model builds on the concept of pedagogical content knowledge (PCK), introduced by Shulman, according to which the essence of teaching is expressed in the ability to present learning content in a way that makes it meaningful, understandable and accessible to learners (Shulman, 1986). It is this specific knowledge that distinguishes the teacher from the specialist in a given subject area and justifies the professional role of the teacher as a mediator between knowledge and the student. Shulman's understanding of pedagogical content knowledge lays the foundations for the modern understanding of the professional competence of the teacher, emphasizing the inseparable connection between what is taught and how it is presented in the learning process. However, with the development of digital technologies and their penetration into education, this two-component perspective proves to be insufficient to explain the complexity of teaching in a technology-saturated educational environment.

In response to these challenges, Mishra and Koehler expanded the concept of PCK by introducing the TPACK model and emphasizing that effective teaching in the modern educational context requires not only pedagogical and content knowledge, but also technological knowledge, as well as a deep understanding of the dynamic interaction between these three components. (Mishra& 2013) We use the TPACK framework to discuss the types of knowledge teachers require to effectively use GenAI tools. (Mishra& 2023) According to the authors, the integration of technology in education cannot be reduced solely to the mastery of technical skills but implies a critical and reflexive understanding of the way in which technology transforms pedagogical strategies, teaching methods and forms of presentation of educational content.

The TPACK model brings together three main areas of professional knowledge – Content Knowledge (CK), Pedagogical Knowledge (PK) and Technological Knowledge (TK), as well as their mutual intersection areas: pedagogical content knowledge (PCK), technological content knowledge (TCK) and technological pedagogical knowledge (TPK). The full integration of these components manifests itself in TPACK as a complex knowledge necessary for effective teaching in a modern, technologically enriched educational environment. Developing TPACK competencies is an essential element in the preparation of future teachers. According to Tondeur et al. (2022), “Teachers acknowledged the importance of the six strategies”. Tondeur work emphasizes enhancing pre-service teachers' Technological Pedagogical Content Knowledge (TPACK) through active, design-based, and collaborative learning rather than traditional methods. Key strategies include using teacher educators as role models, fostering reflection, and engaging in "learning by design. This highlights the significance of instructional strategies for the effective integration of technology into teaching and learning processes. It is important to emphasize that TPACK is not a mechanical collection of three separate types of knowledge, but an integrated and contextually conditioned professional knowledge that arises as a result of their dynamic interaction in a specific educational situation (Koehler & Mishra, 2009).

The manifestation and development of TPACK are influenced by a number of factors, including the characteristics and needs of the learners, the learning objectives, the specificity of the learning content, as well as the available and appropriately selected technological resources. It is this sensitivity to context that makes the TPACK model a particularly adequate theoretical and methodological framework for analyzing and modeling the practical training of future teachers.

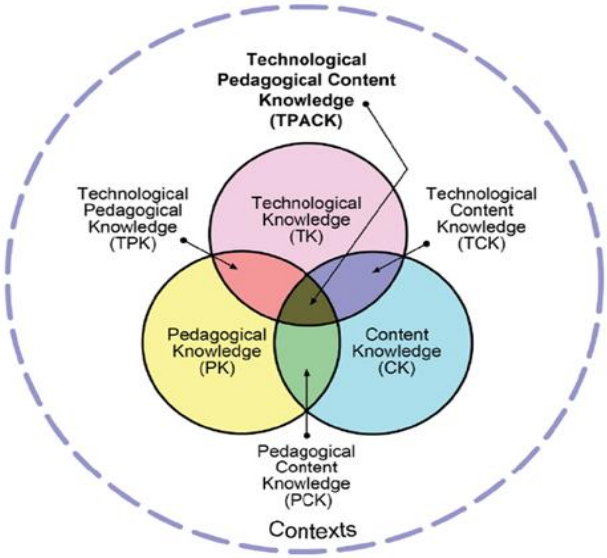
Through the TPACK model, the process of forming professional competencies aimed at integrated pedagogical thinking and effective application of technologies in education can be meaningfully and purposefully planned in the

context of higher education. The main parts of the TPACK model are content, pedagogical and technological knowledge, and it is their integration that is key to the preparation of future specialists in higher education.

Content knowledge encompasses knowledge of the educational content in the field of technology and entrepreneurship - technical processes, economic principles, business models, innovations and sustainable development. Pedagogical knowledge includes: methods, forms and means of training, management of the learning process and assessment of results. Technological knowledge refers to the skills of working with digital tools, platforms and educational technologies.

The essence of the TPACK model lies in the integration of content, pedagogical and technological knowledge in the context of the specific educational situation.

Fig. 1. TPACK Framework (Mishra & Koehler, 2006)



Source: Adapted from Tusiime, Johannesen, & Guðmundsdóttir (2019). / https://doi.org/10.7577/njcie.3313

This integration allows future teachers to purposefully plan, implement and adapt learning activities that combine theory with practice, use technology as a pedagogical tool and respond to the needs and interests of modern students. Through the TPACK model, teaching is seen as a dynamic and reflexive process in which the teacher makes informed decisions about content, methods and technologies depending on the specific learning context, which is why the application of this model is particularly important in the theoretical and practical training of student teachers. In this sense, a number of empirical studies have shown that TPACK represents a particularly effective conceptual framework for the design, implementation and analysis of teacher education programs, as it encourages learners to plan, implement and reflect on their own pedagogical practice in authentic learning situations (Voogt et al., 2013). Effective didactic modeling in technology and entrepreneurship education requires teachers to be prepared for digital learning environments. According to Scherer et al. (2021), "Teachers' readiness for online teaching depends on technological, pedagogical, and organizational factors". This demonstrates the importance of developing TPACK competencies in teacher education. By systematically integrating content, pedagogical and technological aspects, the model supports the formation of comprehensive professional competence, oriented towards practical application of knowledge and conscious use of digital resources in education.

It is these characteristics that make the TPACK model particularly applicable and adequate for the practical training of student teachers in "Technology and Entrepreneurship". The specificity of this educational field, which requires simultaneous mastery of technological content, development of entrepreneurial thinking and application of active pedagogical approaches, implies the use of an integrative didactic model.

Through the TPACK model, future teachers are prepared to design learning situations that combine theoretical knowledge with practical activity, stimulate creativity and initiative in students and meet modern educational requirements. Modern didactic modeling requires not only the use of digital technologies, but also their pedagogically meaningful integration into the learning process. According to UNESCO (2023), "Digital technologies are most effective when combined with appropriate pedagogy and teacher support". This supports the idea that the TPACK model is essential for effective technology and entrepreneurship education."

2.1. Application of the model in the practical training of students

In the context of the training in "Technology and Entrepreneurship", content knowledge (CK) encompasses systematized knowledge of technological processes, economic and entrepreneurial principles, business models, innovations, digital technologies and sustainable development. This interdisciplinary specificity of the teaching content requires from future teachers not only good subject knowledge, but also the ability to pedagogically understand it and adapt it to the age and cognitive characteristics of students. During the internship, students apply the principles of the TPACK model by integrating pedagogical content knowledge (PCK), technological content knowledge (TCK) and technological-pedagogical knowledge (TPK) in the design, implementation and analysis of lessons. Through PCK, the learning content is structured and presented in a clear, logically consistent and methodologically justified manner, through TCK, technologies are used purposefully for visualization, modeling and simulation of abstract or complex technological and economic concepts, and through TPK, pedagogical methods and forms of organization of learning are adapted to stimulate active, interactive and project-oriented participation of students.

This purposeful integration of knowledge supports the formation of professional competence, which allows future teachers to synthesize content, pedagogy and technologies in a real learning context and to make informed didactic decisions. TPACK-based didactic modeling emphasizes the meaningful integration of technology into the educational process. According to the OECD (2023), “Technology should enhance teaching and learning, rather than replace the human interaction at the core of education”. This highlights the importance of pedagogically guided technology use in technology and entrepreneurship education.

Of particular importance in this process is the systematic reflection on the lessons and the analysis of the achieved results, the identification of difficulties and their discussion with a mentor or university lecturer. This reflective practice contributes to the optimization of didactic solutions and the development of skills for pedagogical adaptability and an innovative approach to teaching.

By applying the TPACK model in the practical training of student teachers in "Technology and Entrepreneurship", conditions are created for the targeted development of professional competencies oriented towards the effective use of digital technologies, the application of innovative teaching methods and adequate presentation of the educational content in accordance with modern educational requirements in a real educational environment.

2.2 Model effectiveness research TPACK

The development of digital competence is a key prerequisite for effective technology integration in education. Redecker and Punie (2022) state that “Teachers need digital competence to use technologies confidently, critically and creatively in educational contexts”. This directly corresponds to the technological and pedagogical dimensions of the TPACK framework. In order to establish the effectiveness of the TPACK model as a basis for didactic modeling of the practical training of student teachers in "Technology and Entrepreneurship", an empirical study was conducted. The research tasks were aimed at:

• analysis of the influence of the application of the TPACK model on the formation of professional and entrepreneurial competencies of students;

• establishing students' attitudes towards the use of digital technologies in the educational process and in their future pedagogical practice.

The object of the study was the practical training of students from pedagogical specialties focused on training in "Technology and Entrepreneurship", and the subject of the study was the application of the TPACK model in didactic modeling and implementation of practical and applied learning activities.

To achieve the research goals, a combined methodology was used, including a questionnaire survey and self-assessment of students regarding the level of their professional, pedagogical and digital competencies, as well as the degree of application of the TPACK model in the learning process. The practical training was organized through project-based training, oriented towards the development of educational entrepreneurial projects and the targeted use of digital tools for planning, visualization and presentation of results.

The project activities were structured in accordance with the principles of the TPACK model, seeking integration between the learning content, the applied pedagogical approaches and the used technological tools. In this way, conditions are created for the formation and analysis of integrated professional knowledge and for the development of skills for pedagogical planning, implementation and reflection in a real educational context.

3. RESULTS

The empirical study was conducted among 48 students of the specialty "Pedagogy of Technology and Entrepreneurship Education". For the purposes of the analysis, a five-point Liker scale was applied (1 - very low degree; 5 - very high degree), and the obtained data were processed using descriptive statistics methods, including calculation of average values and standard deviation.

Table 1. Self-assessment of competencies before and after implementing a TPACK-based didactic model

Competency	Before implementation (M)	After implementation (M)	Difference
Planning learning activities	2.9	4.2	+1.3
Applying pedagogical methods	3.1	4.3	+1.2
Using digital technologies	2.7	4.4	+1.7
Working on projects	3.0	4.5	+1.5
Entrepreneurial thinking	2.8	4.1	+1.3

Source: Author

The data in Table 1 show a clear improvement in all the competencies studied after the implementation of the TPACK-based didactic model in the practical training of students. The average increase in the scores demonstrates that the integration of content, pedagogy and technology has a significant impact on the development of professional skills of future teachers of "Technology and Entrepreneurship".

The most significant increase is observed in the competency "Use of digital technologies", with an increase from 2.7 to 4.4 (difference +1.7). This shows that students who before practical training had low confidence in the application of digital tools, after the targeted implementation of the TPACK model demonstrated significantly higher competence. This increase is logical, considering that the model encourages integrated use of technologies in real learning situations, including visualization, simulations and design of entrepreneurial projects.

The next largest increase is the competency "Work on projects", with an increase from 3.0 to 4.5 (+1.5). This shows that students significantly improve their skills in coordinating, planning and implementing learning projects when they are structured within the framework of TPACK. Project-based learning, combined with digital technologies and pedagogical methods, creates conditions for active learning and practical orientation, which reflects the effectiveness of the model for developing integrated competencies.

Competencies related to “Planning learning activities” (+1.3), “Applying pedagogical methods” (+1.2) and “Entrepreneurial thinking” (+1.3) also show significant improvement. That is, students not only master technology and project skills, but also develop their ability to plan and implement learning activities in a systematic and methodically justified manner.

Overall, the results show that the TPACK-based didactic model effectively supports the complex development of students' professional competencies, with a particularly strong impact on digital skills and project work skills. This emphasizes the importance of an integrated approach in the preparation of future teachers in "Technology and Entrepreneurship", which unites content, pedagogy and technology, guiding students towards active, practice-oriented and innovative pedagogical activity.

Table 2. Level of integration of the CK, PK and TK components (from the TRACK model) in practical classes

TPACK Component	Mean (M)	Standard Deviation (SD)
Content Knowledge (CK)	4.3	0.52
Pedagogical Knowledge (PK)	4.1	0.60
Technological Knowledge (TK)	4.4	0.48
CK–PK–TK Integration (TPACK)	4.2	0.55

Source: Author

The average values in Table 2 indicate a high level of mastery and integration of the three main components of the TPACK model. The highest average value was recorded for technological knowledge (TK) – M = 4.4, SD = 0.48, demonstrating strong skills in the use of digital tools and educational technologies. The low standard deviation

shows relatively equal technological readiness among students, which can be explained by the increased role of digital technologies in higher education and their regular application in practical classes.

Content knowledge (CK) was also assessed highly (M = 4.3, SD = 0.52), indicating stable knowledge of technological and entrepreneurial content and successful transfer of theoretical preparation into practice. Pedagogical knowledge (PK) showed a slightly lower but still high mean value (M = 4.1, SD = 0.60), suggesting that students feel more confident in the content and technological aspects than in applying pedagogical strategies and methods. The higher variability in PK emphasizes the need for greater focus on pedagogical practice and reflection.

The integration of all three components (TPACK) achieved a mean value of M = 4.2, SD = 0.55, confirming a good level of integrated pedagogical thinking and the ability to combine content, pedagogy and technology in real educational situations.

Based on theoretical analysis and empirical research, a didactic model for applying TPACK was developed, including the following stages: content analysis (CK), selection of pedagogical approaches (PK), selection of educational technologies (TK), integration of knowledge (TPACK), and implementation and evaluation of practical activities.

The empirical results confirm that the TPACK model improves the quality of practical training and increases students' professional readiness for work in a modern educational environment.

4. CONCLUSIONS

In conclusion, the TPACK model is of key importance for the formation of professional competencies of future teachers of "Technology and Entrepreneurship". Through the integration of substantive, pedagogical and technological knowledge, students develop the ability to critically reflect on the educational content, to effectively use digital technologies and to apply innovative pedagogical approaches. In this sense, TPACK contributes to the preparation of flexible and adaptable pedagogical specialists, meeting the requirements of modern education and the dynamically changing labor market.

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