Teachers' Innovativeness in Using ICT: A DOI-TPACK Perspective

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Abstract

The paper analyzes teachers' innovativeness in the context of using information and communication technologies (ICT). The research objective was to identify the most innovative groups of teachers and to examine whether their professional advancement and/or types of subjects taught influence the quality of ICT use. As a theoretical perspective, the authors have combined the Diffusion of Innovation (DOI) theory with the Technological Pedagogical Content Knowledge (TPACK) model. Data analysis indicated that the teachers with the second degree of professional advancement are more likely to use ICT tools as compared to the teachers with a higher and lower degree of advancement. Additionally, the teachers of science subjects use ICT tools more often than the teachers of humanities. The study also highlights the need for further research considering teachers' demographic characteristics, as well as the drivers and barriers of facilitating the use of ICT tools in primary and secondary education.

Keywords: Teachers, Primary and Secondary Education, ICT, Diffusion of Innovations, TPACK

1. Introduction

In today's educational landscape, the growth of Information and Communication Technologies (ICT) significantly influences teaching and learning. The integration of computers in education serves both as an attribute of societal advancement and a fundamental necessity driven by the present-day job market demands. High competency in ICT tools and digital resources has become an essential skill that students must develop to successfully navigate and thrive in the present and future job market. The promotion of responsible and meaningful use of digital tools should be accompanied by an analysis of how teachers and students perceive these technological advancements [1]. Such analysis is essential for the successful integration of ICT solutions in education sector and for adaptation to the increasing digitalization of learning processes [4]. One of the key challenges in this context is the need to provide adequate support for both teachers and learners [2].

Therefore, the innovativeness of teachers in using ICT is important in enabling students in the area of modern technologies and fostering their digital competencies. In our research, we focused on primary and secondary education for two reasons. In the majority of societies,

most citizens go through these levels of education and then enter the labor market, therefore observations made for these two phases of education will be valid almost for the entire working population. However, if some people decide to continue their education at a higher level, good preparation in the use of IT tools will allow them to study effectively and efficiently.

The authors of this paper conducted a large empirical sample-based study, with the primary goal to assess the level of computerization in primary and secondary schools. The study focused on understanding how teachers use available ICT tools for teaching and communicating with students. For this purpose, the authors analyzed, among other things, the spread and frequency of use of ICT tools by teachers and the impact of their technological skills, combined with experience (pedagogical and substantive knowledge), on the use of these tools. This led to the analysis and conclusions presented in this article.

The goal of this study is connecting the theory of Diffusion of Innovation (DOI) [11] with the model of Technological Pedagogical Content Knowledge (TPACK) [8,9,10] in which we map original adopters' categories into relevant types of knowledge for indicating the most innovative groups of teachers. In our opinion, the use of the proposed theoretical framework (Figure 3) that originally combines the above-mentioned theories, addresses a substantial research gap. This will allow us to fulfill the main goal of the study and obtain valuable answers to the formulated research questions (see Section 3).

2. Research Background

In 1986, Schulman proposed a new way of describing the knowledge that a teacher must have to effectively and efficiently teach the content of a given subject. The introduced construct of pedagogical and subject knowledge (PCK) refers to the question of "what" and "how to teach" [13]. PCK is a combination of pedagogical competencies and relevant domain knowledge. Given the dynamic development of ICT and the expanding spectrum of digital tools, which can be used in the teaching process, teachers' knowledge and competencies in using new technologies are also becoming increasingly important. This is reflected in the Technological Pedagogical Content Knowledge model (TPACK), which creates an extensive framework for describing the types of knowledge that a teacher should have to successfully integrate technological tools in the teaching process [9], [16]. The interaction between Technological Knowledge (TK), Pedagogical Knowledge (PK) and Content Knowledge (CK) is a requirement for the successful integration of technology in teaching processes (Figure 1). Equipping teachers with TPACK knowledge assumes learning and adopting technological innovations (TK).

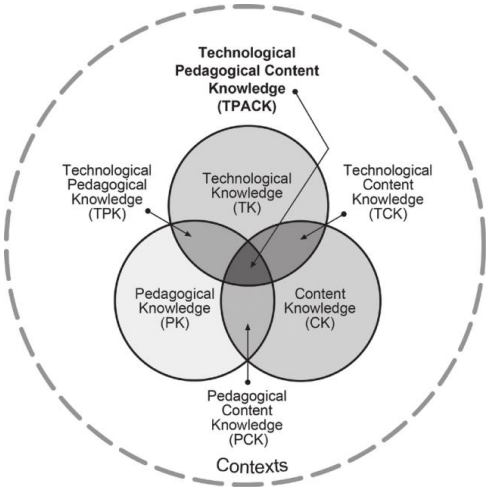

Fig. 1. The TPACK framework (reproduced by permission from http://tpack.org/)

The process of adapting innovative technologies can be described based on Rogers's theory of Diffusion of Innovations (DOI) [11], which emphasizes the role of communication

in the adoption of innovations in various social systems [12]. The acceptance of new technology in this approach proceeds through five stages (Knowledge, Persuasion, Decision, Implementation and Confirmation) [10].

The DOI theory also indicates different attitudes towards emerging innovations and identifies five categories of adopters (Figure 2):

- Innovators (about 2.5% of the population) – the first to adopt an innovation. They are courageous, like to take risks, and have contacts outside the local social system.
- Early Adopters (about 13.5% of the population) – opinion leaders in their social system. They are respected and often consulted by others. They adopt innovations relatively early, but with more deliberation than innovators.
- Early Majority (about 34% of the population) – deliberate, adopting innovations somewhat later than early adopters. They take longer to make decisions and often wait for evidence of benefits.
- Late Majority (about 34% of the population) – skeptical, adopting innovations only after the majority has already done so. They often respond to social pressure and are afraid of risk.
- Laggards (about 16% of the population) – the last to adopt an innovation. They are traditional, reluctant to change and often socially isolated.

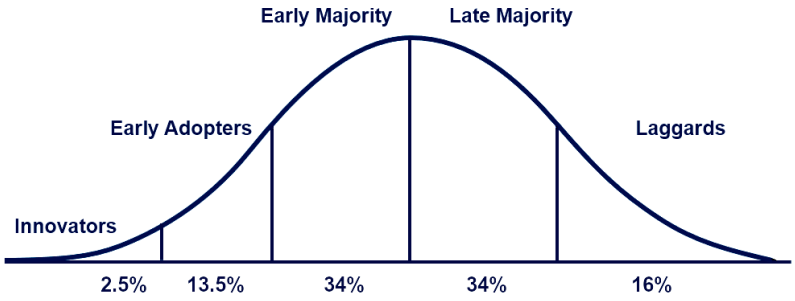

Fig. 2. Five categories of adopters in the DOI theory (adapted from [11], p. 247)

The same diffusion mechanism applies in education and explains why some teachers, and some schools adapt new digital tools to the teaching processes more rapidly [3]. The later aspect of DOI constitutes the central perspective of our research framework (Figure 3).

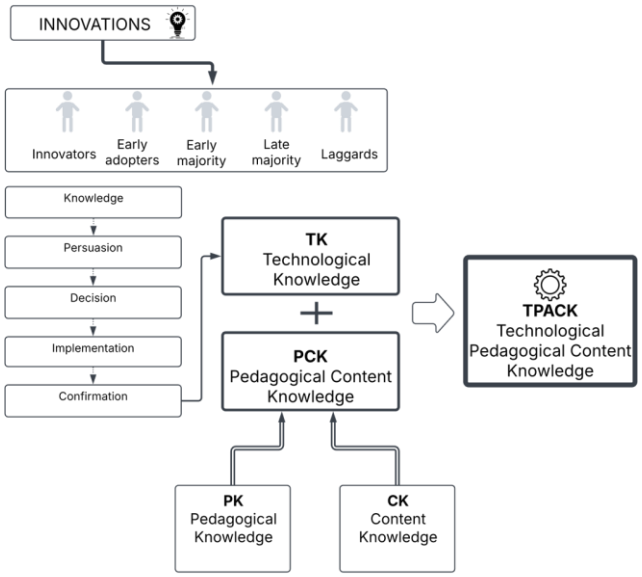

Fig. 3. Research framework

3. Research Objectives

Our study is aimed at examining the use of ICT tools in primary and secondary schools. By combining the DOI and TPACK, we seek to identify the most innovative groups of teachers and determine whether the most innovative group includes teachers who have the highest competencies defined in the TPACK model. For this analysis, we assumed that teachers would be categorized according to the TPACK model based on their level of professional advancement and the nature of the subjects they teach. The determination of pedagogical competencies (PK) and content-focused competencies (CK) is based on the level of teachers' professional advancement, which, in accordance with legal regulations in Poland, directly assumes that teachers with greater PK and CK competencies have a higher level of professional advancement. Advancement to a higher professional grade in Poland is associated with the necessity of meeting increasingly higher requirements concerning both pedagogical competencies (teaching methods, work with students, assessment, upbringing) and subject-matter competencies (knowledge of a given subject, the ability to convey it). A teacher at the highest level of professional advancement should be a role model in both areas and actively contribute to improving the quality of the school's work.

The determination of technological competencies (TK) is based on the adopted assumption that teachers of science-related subjects, due to their education and the nature of the classes they teach, have greater technological competencies.

Such assumptions allowed us to define the following research questions:

- **RQ1**: *Are the teachers with the highest level of professional advancement the most innovative in their use of ICT in teaching?*
- **RQ2**: *Are the science teachers more innovative in their use of ICT than humanities teachers?*

4. Research Procedure

The study was conducted in February-March 2024 in the city of Tarnów in Poland. It was preceded by a pilot study and consisted of two stages – a survey among principals of primary (7) and secondary (13) schools and an anonymous survey of teachers working in these schools. During the study, 20 surveys were collected from school principals and 314 surveys from teachers. It should be noted that at the time of the study, there were 37 schools in Tarnów (14 primary schools and 23 secondary schools), which means that the study covered 54% of all Tarnów schools. The questionnaires were available online and a request to participate in the study was sent to individual schools through their governing body – the Department of Education of the City of Tarnów.

Based on the collected data, we have outlined the profile of the respondent (teacher), which consists of, among others: their gender, age, place of work, subject taught, years of experience in the teaching profession and the level of professional advancement. Almost 3/4 of the respondents (73.8%) are women. The age distribution of the teachers surveyed is as follows: 16.5% are people under 40, 38.8% are people aged 40-49, 44.7% are people aged 50 and over. The data obtained show that 13.9% are people with less than 10 years of experience, 24.2% are people with 11-19 years of experience, 61.8% are people with more than 20 years of experience. It should be noted that the distribution of respondents is consistent with the distribution of teachers in Poland in terms of gender and age, and it aligns with the data provided by the Ministry of National Education [14].

Among the respondents, 51% are teachers of humanities (designated with the letter "H"), and 49% are teachers teaching science subjects (designated with the letter "S"). In the Polish education system, teachers can be employed in positions corresponding to the levels of professional advancement, which are specified in the act – the so-called Teacher's Charter [7] and the Regulation of the Minister of Education and Science on detailed qualifications required from teachers [5]. There are 3 levels of professional advancement:

- 1st level (the lowest, in Polish referred to as "beginning teacher" – in original "nauczyciel początkujący"),
- 2nd level (medium, "appointed teacher" – "nauczyciel mianowany"),
- 3rd level (the highest, "certified teacher" – "nauczyciel dyplomowany").

Among the teachers surveyed: 11.2% are teachers at level 1, 14.8% are teachers at level 2, 74% are teachers at level 3.

For the purposes of analysis and presentation of results, 6 groups of teachers were distinguished, considering the subjects taught (scientific or humanities) and the level of professional advancement. These groups were marked as: (S1) – science teachers at level 1, (S2) – science teachers at level 2, (S3) – science teachers at level 3, (H1) – humanities teachers at promotion level 1, (H2) – humanities teachers at level 2, (H3) – humanities teachers at level 3.

5. ICT Tools Used in Schools

According to The Digital Competence Framework for Educators (DigCompEdu), teachers are expected to develop digital competencies across 6 areas, which collectively comprise 22 specific competencies [15]. In light of rapid technological advancements, contemporary educators have access to a diverse array of ICT tools and digital resources, which they can strategically implement across various areas of their work – from professional engagement and digital resource management, through planning and delivering teaching and learning, to assessment and fostering learners' digital competence (Table 1).

Table 1. Area of Digital Competence for Teachers and ICT Tools (based on [15])

Area	Competences	Example ICT Tools
Professional Engagement	Organizational communication, Professional Collaboration, Reflective Practice, Digital Continuous Professional Development	Groupware platforms (e.g. MS Teams, Google Workspace); Video conferencing platforms (e.g. Zoom, MS Teams, Google Meet); Communication programs (e.g. e-mail, Skype, Messenger, WhatsApp), Social media platforms (e.g. Facebook, Twitter/X); Teacher platforms (e.g. Edmodo, TeacherTube); E-learning platforms (Udemy, Moodle, Blackboard); Educational blogs and portals
Digital Resources	Selecting digital resources, Creating and modifying digital content, Managing, protecting and sharing digital resources	Internet search engines (e.g. Google Search, Google Scholar, ResearchGate); Open Educational Resource Repositories; Digital libraries; Public institution websites; Social media platforms; Word processors (e.g. MS Word, Google Docs, LibreOffice Writer); Spreadsheets (e.g. MS Excel, Google Sheets); Presentation tools (e.g. MS PowerPoint, Prezi, Canva, Sway); Graphics editors (e.g. GIMP, Canva); Video editing tools (e.g. Shotcut, DaVinci Resolve); Audio recording tools (e.g. Audacity); Interactive content creation tools (e.g. Quizizz, Kahoot!, Quizlet); Blogging platforms (e.g. WordPress, Blogger); Website creation tools (e.g. Google Sites); Cloud storage (e.g. Google Drive, MS OneDrive); Learning Management Systems (e.g. Moodle, Google Classroom, MS Teams)
Teaching and Learning	Teaching, Guidance, Collaborative learning, Self-regulated learning	Learning Management Systems; Word and presentation editors; Video conferencing platforms; Communication programs; Digital whiteboards (e.g. Jamboard, Miro, Google Draw); Poll and quiz tools (e.g. Kahoot!, Quizizz); Interactive lesson creation tools (e.g. Nearpod, Pear Deck, Genially); Video (e.g. Shotcut), graphic (Canva, GIMP) and text editing tools; Translation tools (e.g. Google Translate); Group project and collaboration tools (e.g. Google Workspace, MS 365, Trello, Asana); Presentation tools
Assessment	Assessment strategies, Analyzing evidence, Feedback and Planning	Learning Management Systems with assessment modules (e-gradebooks); Quiz and test creation platforms (e.g. Google Forms, MS Forms, Kahoot!, Quizlet); Anti-plagiarism systems (e.g. Plagiat.pl, Turnitin); Spreadsheets; Data visualization tools (e.g. Tableau, Power BI); Commenting functions in text editors
Empowering Learners	Accessibility and inclusion, Differentiation and personalization, Actively engaging learners	Interactive content creation platforms (e.g. H5P); Mind mapping and visual note-taking tools (e.g. Coggle, XMind, Jamboard); Multimedia creation and editing platforms (e.g. Canva, GIMP, Audacity); Programming tools (e.g. Scratch, Code.org, Python IDEs); Educational gaming and gamefication platforms (e.g. Kahoot!, Quizizz); Learning Management Systems with personalization features; Modifiable learning resources (e.g. files in word processors, spreadsheets); Translation tools (e.g. Google Translate); Collaboration platforms (e.g. Google Docs, Microsoft 365, Padlet, Miro); Online discussion platforms (e.g. MS Teams)
Facilitating Learners' Digital	Information and media literacy, Digital	Interactive online courses and tutorials (e.g. Code.org, Khan Academy, Duolingo); Text editors, spreadsheets, presentation programs; Operating systems and mobile applications; Graphics editors; Presentation tools; Video

Competence	communication and collaboration, Digital content creation, Responsible use, Digital problem solving	editors (e.g. Shotcut); Blogging and website creation platforms (e.g. WordPress, Google Sites); Multimedia storytelling tools (e.g. Storyboard That, Book Creator); Programming tools; Video conferencing platforms; Online collaboration tools (e.g. Google Docs, Miro, Trello); Asynchronous communication tools; Online threat scenario simulations; Cybersecurity educational platforms (e.g. CERT Polska); Copyright and licensing resources (e.g. Creative Commons); Discussion materials on cyberbullying, technology addiction, disinformation; Technical support forums, knowledge bases; Platforms with logical and problem-solving challenges (e.g., websites with programming tasks); Tools for searching for information and critically evaluating sources (internet search engines, fact-checking sites).

The collected data shows that the most popular tool for communication between teachers, students, parents and school management is the electronic gradebook (e-gradebook), which has currently replaced paper gradebooks. The advantage of the e-gradebook is an easy access to information about the student's progress in learning, attendance and homework, as well as convenient communication between teachers, students and their parents. In accordance with the regulations in force in Polish law [6], teachers can communicate with students outside of classes only through official channels, such as the e-gradebook, official e-mail and portals intended for remote learning at school (educational portals). This was reflected in the obtained data, which shows that most teachers use the tools permitted for this type of contact, such as the e-gradebook (95.8%) and e-mail (84.1%). Communication tools such as chat (e.g. Skype, Messenger, WhatsApp) are also used relatively often (48.9%).

Apart from communication and delivering lessons, teachers' work also involves managing classroom activities, assessing student progress, preparing syllabuses, didactic materials and presentations needed for learning, which make the educational process easier and more attractive. For this purpose, teachers often use word processors (76.4%), presentation tools (72.8%), thematic websites (67.3%), spreadsheets (42.1%), as well as educational platforms (60.8%) and share video materials posted on websites (76.4%) or even content from social media (24.6%). An inherent element of teaching at school is also testing the knowledge acquired by students – a significant number of teachers use quizzes for this purpose (41.1%).

6. Use of ICT Tools by Teachers

The collected data indicates that teachers expressed their opinion on various aspects of the use as well as usefulness of ICT tools and digital materials. For the purposes of this analysis, the questions that express most about the innovativeness and level of use of ICT tools were considered. These questions are related to the use of ICT tools (a) during lessons, and (b) when preparing for classes (development of ICT has a positive impact on preparation), and (c) the opinion on the impact of ICT development on changing the way classes are conducted. The answers to these questions are presented in Table 2.

Table 2. Use of ICT Tools by Teachers

To what extent do you agree with the following statements?	**not at all**	**rarely**	**some-times**	**often**	**always**
(a) I use ICT tools during lessons	2,6%	6,5%	15,2%	42,0%	33,7%
(b) I use ICT tools when preparing for classes	0,7%	2,6%	7,8%	48,5%	40,4%
(c) The development of ICT is changing the way I conduct my classes	1,9%	6,5%	19,1%	42,7%	29,8%

The data comparison allows us to state that the continuous use of ICT tools (answers "always") by teachers is at the level of 30-40%. According to DOI theory, this suggests that ICT integration is primarily driven by the most progressive user groups, i.e., Innovators, Early Adopters, and the Early Majority [11].

In accordance with the proposed division, we have compared the responses of science teachers at each level of professional advancement (S1, S2, S3) with the responses of humanities teachers (H1, H2, H3). The results are presented in Table 3. When comparing the results, it can be stated that the group of the most innovative teachers includes teachers who

have the 2nd level of professional advancement (S2 and H2). This indicates that the answer to the research question RQ1 is negative – i.e. teachers with the highest level of advancement (S3 and H3) are not necessary the most innovative. Although the difference between these groups is not large (usually does not exceed 10%), it is present in the responses to all questions.

Since a negative answer to question RQ1 may be interpreted at first glance as inconsistent with the TPACK model, additional analysis is necessary here, which will primarily consider the age of teachers. Age may be one of the factors that – despite teachers meeting the competency criteria defined in the TPACK model – negatively affects their innovativeness. Additionally, in a situation where almost half of the surveyed teachers (44.7%) are 50 years old or older, this factor may pose a real threat to the future use of ICT tools by this group of teachers and requires in-depth analysis.

Additionally, it is worth noting that the least innovative teachers are those who are at the 1st level of professional advancement (S1 and H1). In this case, it is fully consistent with the TPACK model, especially since the difference between them and teachers at the 2nd level of professional advancement (S2 and H2) is significant and usually amounts to a dozen or so percent.

Table 3. The Use of ICT Tools by Teachers of Science Subjects (S1, S2, S3) and Humanities Subjects (H1, H2, H3) – "always" answers

To what extent do you agree with the following statements?	**Answers**		**Answers**		**Answers**	
	S1	**H1**	**S2**	**H2**	**S3**	**H3**
(a) I use ICT tools during lessons	22,7%	16,9%	41,7%	42,9%	34,4%	31,8%
(b) I use ICT tools when preparing for classes	40,9%	25,0%	52,3%	40,1%	41,9%	39,8%
(c) The development of ICT is changing the way I conduct my classes	27,8%	24,9%	41,7%	38,1%	29,1%	27,0%

When looking for an answer to question RQ2, it can be noticed that teachers of science subjects (with one exception – question "a" answers S2 and H2) use ICT tools to a greater extent than teachers of humanities subjects. This means that they can be considered more innovative and – in accordance with the adopted assumptions and the TPACK model – a positive answer to question RQ2 can be provided. However, it should be noted that in two cases the difference between the values is relatively small and amounts to 2.1% (questions "b", "c" answers S3 and H3).

7. Conclusion, limitations and future work

The presented research may be considered as a contribution to the literature on the subject related to the implementation and use of ICT in education. According to performed analyses, it will allow for:

- a better understanding of the factors influencing the use of ICT tools in schools,
- the identification of barriers to the implementation and use of ICT,
- the comparison of the implementation of ICT tools in different contexts and schools with different levels of innovation.

Outcomes of our study can also potentially benefit educational practice in terms of:

- better implementation and use of ICT in schools,
- organizing more effective training for teachers considering digital competencies in accordance with the TPACK model,
- creating support programs for teachers-laggards.

The conducted analyses allowed us not only obtain answers to the formulated research questions, but at the same time indicated areas requiring in-depth study. One of the gaps requiring further research is the inclusion of teachers' levels of advancement in using ICT tools. These levels can vary significantly, with some teachers using the tools at a basic level and others demonstrating advanced expertise. This may potentially affect the innovation in a

significant manner. Previous studies have assessed the knowledge and usage of specific ICT tools, but only among teachers of computer science and technical subjects

Therefore, in the future, the authors plan to continue their research in this area through:

- an analysis that will explain why – contrary to the assumptions made in the TPACK model – the answer to question RQ1 is negative,
- an analysis of teachers' innovativeness in other cross-sections (including gender, age and subject taught) and an analysis of the distribution of "later groups" of users in the DOI theory, i.e., Late Majority and Laggards,
- further research that will allow to determine teachers' levels of advancement in using ICT tools, as well as to identify the key drivers and barriers influencing the adoption of ICT innovations among educators.

Regardless of the presented analyses devoted to the DOI theory and the TPACK model, it should be noted once again that the presented results represent only a fragment of broader research devoted to the use of ICT tools by teachers and the article presents aggregated data. The authors will follow the detailed analysis of empirical data that will allow for a better understanding of using ICT tools by teachers (considering factors as age, gender, skills, subject taught), which is a key foundation for designing and developing more effective, tailored and supportive IT tools and systems for the education sector. In particular, considering differences in the level of innovation and preferences of individual groups of teachers can have a beneficial effect on the creation and provision of new ICT solutions and tools that they will be able to use successfully. Work in this area is already underway, and its results will be presented in the future publications. Additionally, the authors plan to conduct an additional research on the same group of respondents (a follow-up study) to verify and expand upon the initial findings, as well as to monitor possible changes that may occur, in particular as a result of the development of artificial intelligence.

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