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Digital Competencies of Future Preschool and Early Primary Education Teachers: Challenges and Developmental Perspectives – the Photon Educational Robot: A Case Study

Kompetencje cyfrowe przyszłych nauczycieli edukacji przedszkolnej i wczesnoszkolnej: Wyzwania i perspektywy rozwoju – na przykładzie robota edukacyjnego Photon

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Abstract

Aim. The aim of this article is to analyse various terminological approaches to digital competences and to present the results of a study on the use of the Photon educational robot as an innovative tool implemented in the education of third-year full-time undergraduate students enrolled in the Preschool and Early Childhood Education program at the Faculty of Education, University of Bialystok. The study sought to examine the digital competences of students in preschool and early childhood education and their readiness to implement new technologies in the education of young children.

Methods and materials. The study employed an approach combining a literature review with original quantitative research. A diagnostic survey method was used, applying a questionnaire technique. The students completed the same questionnaire before and after the implementation of the educational activities. The mean scores from the pre-test and post-test measurements were compared, using the paired-samples

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Student's *t*-test, in order to determine the statistical significance of the implemented educational intervention.

Results and conclusion. The results of the educational intervention conducted among the students, which combined theoretical and practical components related to the potential use of the Photon robot, demonstrated that the implemented activities contributed to the optimisation of students' digital competences and increased their readiness to use new technologies. By becoming familiar with the functions of the device, the students broadened their understanding of its potential applications and were prepared to develop their own educational materials in the form of lesson plans.

***Keywords*:** digital competences, new technologies, ICT, Photon robot, teacher education, student education, AI

Abstrakt

Cel. Celem niniejszego artykułu jest dokonanie analizy różnych podejść terminologicznych dotyczących kompetencji cyfrowych oraz prezentacja wyników badań dotyczących zastosowania robota edukacyjnego Photon jako innowacyjnego narzędzia wdrożonego w proces kształcenia studentek 3 roku studiów stacjonarnych kierunku pedagogika przedszkolna i wczesnoszkolna Wydziału Nauk o Edukacji Uniwersytetu w Białymstoku, których celem było poznanie kompetencji cyfrowych studentek kierunku pedagogika przedszkolna i wczesnoszkolna oraz ich gotowości do wdrażania nowych technologii w edukacji najmłodszych.

Metody i materiały. W artykule zastosowano podejście łączące analizę literatury z autorskimi badaniami ilościowymi. Posłużono się metodą sondażu diagnostycznego przy zastosowaniu techniki ankiety. Studentki wypełniły kwestionariusz przed oraz po realizacji działań dydaktycznych. Średnie wartości wyników z pomiaru początkowego i końcowego porównano z wykorzystaniem testu t-Studenta dla prób zależnych w celu określenia istotności statystycznej zastosowanej interwencji dydaktycznej.

Wyniki i wnioski. Wyniki interwencji dydaktycznej zawierającej teorię i praktykę w kontekście możliwości wykorzystania robota Photon ukazały, że warunkuje ona zoptymalizowanie kompetencji cyfrowych wśród studentek, a także wpływa na wzrost ich gotowości do wykorzystywania nowych technologii. Dzięki poznaniu funkcji urządzenia, studentki poszerzyły swoją wyobraźnię na temat możliwości jego wykorzystania, a także były gotowe do tworzenia własnych materiałów edukacyjnych w postaci scenariuszy zajęć.

***Słowa kluczowe*:** kompetencje cyfrowe, nowe technologie, TIK, robot Photon, kształcenie nauczycieli, kształcenie studentów, AI

Introduction

The dynamic development of information and communication technologies (ICT), and their increasing significance in various aspects of life, also generate a growing demand for the use of these devices, within the school environment. The concept of rapid access to information in education encompasses both access to the Internet and the use of modern technologies during lessons that facilitate the acquisition, processing, and creation of data. The presence of these solutions within the education system implies the necessity of modifying teaching methods and instructional resources supporting the learning process. They also require the continuous updating of teachers' knowledge and competences, whose role is no longer limited solely to integrating ICT with traditional methods of instruction, but also includes the ability to create educational materials aimed at supporting students in the conscious and responsible use of modern technologies, as well as developing the ability to select available sources while prioritising the privacy and safety of those in their care (Yakubov, 2023).

At present, the use of devices such as laptops, multimedia projectors, photocopiers, or interactive whiteboards has become a standard element of school equipment and no longer constitutes a factor enhancing the attractiveness of the teaching process. There is an expectation to employ more advanced technological solutions, which include: tablets, interactive floors (so-called *magic carpets*), educational robots, as well as augmented reality (AR) and virtual reality (VR) technologies. In the face of these changes, digital competences have become a key component of teachers' professional practice. They encompass a range of activities, including designing engaging lesson scenarios, creating and using interactive and creative instructional tools, as well as programming educational robots (Morańska, 2023).

Higher education institutions, as entities responsible for educating future teachers, play a significant role in the mental and practical preparation of students for work in a dynamically changing educational environment. Direct engagement with educational materials may foster an understanding of the possibilities for their application; therefore, appropriate equipment of institutional units plays a key role in this regard. Strengthening students' digital competences is essential so that, as future teachers, they are able to use modern tools effectively, creatively, safely, and with due respect for moral values in the teaching and educational process (Abella, 2025). This constitutes an important element of their professional preparation and provides a competitive advantage through the diversification of their professional profile, which is crucial for young pedagogues entering the labour market (Joya *et al*., 2025).

In this article, I undertake an analysis of various definitional approaches concerning digital competences. I present the results of the implementation of the Photon educational robot as an innovative tool introduced into the educational process

of third-year full-time students enrolled in the Preschool and Early School Pedagogy programme at the Faculty of Education of the University of Białystok. The article includes the results of research aimed at identifying the digital competences of students of Preschool and Early School Pedagogy and their readiness to implement new technologies in the education of the youngest learners. In particular, the study examines whether the introduction of issues related to the Photon educational robot optimises students' digital competences and increases their readiness to use new technologies during school lessons, as well as what types of new technologies applicable in school education are known to the students. This issue is particularly important in light of the growing significance of digital technologies in contemporary education and the need to prepare future teachers to use them in a reflective, purposeful and pedagogically justified manner.

Digital Competences – Theoretical Foundations

Digital competences in children's education fulfil three key roles: they influence individuals and the learning environment, offer new opportunities for improvement, and integrate ICT with teaching practice and the directions of educational policy development (Bolstad, 2004). The indicated areas demonstrate the importance of education oriented towards preparing the younger generation for conscious functioning within a digital society and for active civic participation. Achieving these objectives requires appropriate preparation of the teaching staff.

In the context of research on digital competences, the position adopted by Motylińska and Musiał constitutes a valuable point of reference (Motylińska & Musiał, 2019). According to the authors, digital competences comprise a set of skills, knowledge, and attitudes that enable the conscious, critical, and effective use of digital technologies in the teaching process, professional work, and active participation in the information society. Knowledge in this area concerns an understanding of the role of digital technologies in communication, recognition of their creative and innovative potential, as well as an awareness of the consequences and potential risks arising from their use. Skills encompass such abilities as the use of digital content, its practical application through the creation of digital instructional materials, as well as the implementation of tools based on artificial intelligence or robotics. Attitudes, in turn, refer to the reflective and critical engagement with technologies and digital content (Motylińska & Musiał, 2019). A different position is adopted by Michalska (2024), who defines these competences as the ability to integrate various sources of information and to synthesise knowledge. According to Plebańska (2018), digital competences encompass proficiency in searching for an understanding of information received from the Internet, as well as the ability to assess its credibility and usefulness. They also

include fluency in operating a computer and other electronic devices, as well as possessing the competences necessary to create digital materials. The definition of digital competences presented in the article "Media cyfrowe a edukacja dziecka" [Digital media and children's education], constitutes a synthesis of the three previously discussed approaches. The authors emphasise the importance of understanding the It environment, the language of the media, and their impact on society, which contributes to the safe use of technological tools and to conducting a conscious analysis of content published online (Walter *et al*., 2020).

A set of technological tools used for transmitting, collecting, processing, and managing information is referred to as ICT (Walter *et al*., 2020). Goban-Klas (1999) indicates that the concept of information technologies may be synonymous with new media, which he defines as electronic means supporting communication. New media, in contrast to traditional media (press, radio, television), are characterised by a higher degree of interactivity, greater dynamism, and a broader range of transmission possibilities (Seklecka, 2010). They include electronic means whose popularity largely results from widespread access to the Internet. Their primary function is to integrate various forms of content presentation and communication channels – both traditional and digital (Wasiuta & Klepka, 2019). In early education, the term ICT encompasses various types of hardware and software: computers, digital cameras and camcorders, the Internet, mobile phones, tablets with mobile applications, interactive environments and computer games, programmable toys, projectors, interactive whiteboards, and many others (Bolstad, 2004). In my view, this group should also include modern educational equipment, such as interactive robots, interactive floors and educational blocks, touch monitors, 3D printers, 3D pens and scanners, as well as VR/AR headsets. ICT tools are complemented by programmes and applications, including text and presentation editors, mind-mapping tools, digital comic creators, word cloud generators, software for editing photographs, posters, films, music, or podcasts. Graphic editors, worksheets and flashcard generators, as well as tools for creating games, QR codes, puzzles, or quizzes also play an important role in lesson preparation. Within the sphere of educational resources, one may also distinguish expert blogs, thematic portals, online encyclopaedias and dictionaries, virtual exhibitions, e-books, and multimedia programmes (Plebańska, 2018). Among the new media applied in education, generative artificial intelligence models may also be included, such as ChatGPT, Claude AI, Bing, or BERT, which support the information processing process, provide rapid access to literature, assist in adapting materials to students' needs, and facilitate the creation of educational content through the generation of instructional materials, such as worksheets, quizzes, or tests (Michalska, 2024).

Photon Robot – as an Example of a Device Developing the Digital of Students, Teachers, and Pupils

The Photon robot is an interdisciplinary device and an educational innovation developed by the Polish company Photon Education (Karpińska, 2022). The aim of the project was to support the work of educators conducting classes both with children and with students in higher grades (Photon Education, 2025). It is an interactive robot that supports young children and adolescents in the development of basic skills in the areas of robotics and coding, physics, special educational needs, artificial intelligence, ecology, and social-emotional education (Karpińska, 2022). In appearance, it resembles a friendly pet; it is intuitive to operate and responds to touch, colours, and sounds. It stimulates students' curiosity and emotions. It moves with an accuracy of up to 1 cm, which enables the teacher to engage students in the world of mathematics and sequences, constituting a fundamental step in the development of programming skills (Photon Education, 2025).

The first prototype of this device was created in 2014. In striving to develop the most optimal solution possible for teachers, children, and their parents, its co-design was necessary. Consequently, until 2017, the robot's construction underwent significant modifications. The preparation of the final version of Photon involved cooperation with 40 teachers, 350 children and 200 parents, who had differing prime expectations of the product, including:

1. Parents (subconscious learning, development, motivation, safety of use, user-friendly sounds, intelligent entertainment, learning programming, *etc*.);
2. Teachers (control via mobile device, attractiveness for children, combining learning with entertainment, supporting group work, differentiation of difficulty levels);
3. Children (moving around, lighting up, speaking, executing commands).

The new and final version of the robot was tested by 3000 children as well as in 50 primary schools and kindergartens. The robot's appearance and construction had to meet the following criteria: a universal and attractive design, size, and weight adapted to the needs of a child, and durability. The application enabling control of the device, in turn, had to be clear and adjusted to the child's age and abilities. Therefore, four interfaces were developed, differentiated in terms of technique and level of difficulty: Joystick, Photon Draw, Photon Badge, and Photon Block. Each interface makes it possible to dictate the robot's route in a different manner, depending on the child's age, stage of development, and the amount of time allocated to exercise with the robot. Additionally, the application offers ready-made activities that facilitate the teacher's work while simultaneously enhancing the attractiveness of classes, for example, Photon can randomly select a sound or colour, divide participants into groups, and also function as a wheel of fortune (Photon Educations, 2025).

The enterprise, which originated from the academic centre of the Białystok of Technology, currently operates as an independent company, supplying its products to the international market. These solutions are already used by more than 15,000 institutions and over one million students across six continents. The company has received high-level distinctions, including the prestigious Education Alliance Finland (EAF) certificate and recognition from the International Society for Technology in Education (ISTE) (Photon Education, 2025).

Since 2023, Photon Education has commenced cooperation with the Faculty of Education at the University of Białystok. The intention of this initiative is to support the development of innovative education and to enhance the quality of training provided to future preschool and early school teachers. Students complete a course on operating the Photon educational robot, become acquainted with its structure and capabilities, and subsequently develop their own lesson scenarios which, under the supervision of an academic teacher, they publish on the educational portal portal.photon.education.pl (Faculty of Education, n.d.). This is an important initiative that enables students to experience to dimension of new technology and to develop their digital competences prior to entering the labour market.

Author's Own Research Procedure

The aim of the author's own anonymous research conducted in 2024 at the Faculty of Education of the University of Białystok was to identify the digital competences of students enrolled in the Preschool and Early School Pedagogy programme. The participants gave their consent to the measurement and took part in classes devoted to learning about the specificity of the functioning and programming of the Photon educational robot. The following research problems were formulated: Does the introduction of issues related to the Photon educational robot condition the optimisation of students' digital competences? Does the introduction of content related to the Photon educational robot optimise the increase in students' readiness to use new technologies during school lessons? What types of new technologies that may be applied during school lessons are known to the students?

The study involved 71 respondents aged between 21 and 25 years. The entire group consisted of women students of Pedagogy specialising in Preschool and Early School Pedagogy. Quantitative research of an experimental character was conducted, and the diagnostic survey method was employed. The survey technique was applied, with a questionnaire used as the research instrument. The respondents assessed their own skills using a five-point scale and answered open-ended questions.

The selection of the experimental method resulted from the nature of the formulated research problems. This method made it possible to conduct measurements before and after the didactic intervention, which allowed for the assessment of changes occur-

ring in the examined variables. Within the adopted research procedure, two measurements were carried out using the same original questionnaire: the pre-test took place during the first class, whereas the post-test was conducted after the completion of 15 hours of instructional exercises. The organisation of such a procedure enabled me to assess whether the introduction of issues related to the Photon educational robot conditions the optimisation of students' digital competences, as well as whether it increases their readiness to use new technologies during school lessons.

The statistical analysis was performed using the SPSS software. In order to assess the impact of the organised procedure involving the Photon educational robot, Student's *t*-test for dependent samples was applied. Student's *t*-test is a test of the significance of differences between two means established on interval scales (Maszke, 2004). This procedure made it possible to compare the means obtained from measurements conducted within the same research group at two time points – before and after the didactic intervention. The application of this tool allows for the assessment of whether the observed change is statistically significant, which constitutes the basis for drawing conclusions regarding the effectiveness of introducing the educational robot into the students' didactic process. Although the variable was measured on a five-point scale, following Geoff Norman (2010), it was assumed that such scales in social research may be treated as approximate interval scales, which enables application of Student's *t*-test within the adopted research procedure.

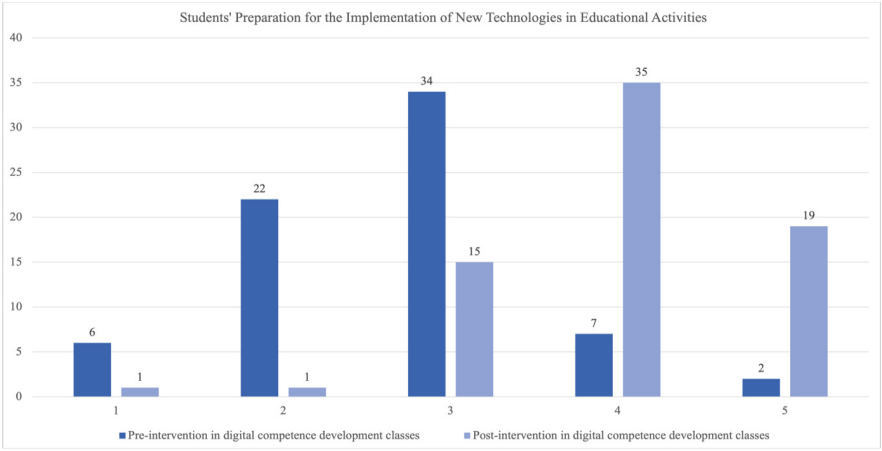
Results of the Author's Own Research

The results of the first measurement indicated that slightly more than half of the surveyed students (53%) had ever heard of the Photon educational robot. At the same time, only a small number of them declared that they would be able to use this device independently during educational classes. The analysis showed that the mode of the ratings concerning self-assessed ability to programme the robot was the values of 2, indicated by 25 students (Figure 4).

In order to conduct a comprehensive assessment of the effectiveness of the didactic intervention, a measurement of the students' self-assessment regarding their preparedness to introduce new technologies was carried out at two time points: before, and after, the completion of the classes. The mean score prior to the intervention was $M = 2.68$ ($SD = 0.87$), whereas after the intervention it increased to $M = 3.99$ ($SD = 0.82$). Analysis using Student's *t*-test for dependent samples demonstrated a statistically significant increase in the level of preparedness, $t(70) = -9.09$, $p < .001$, with a mean difference of -1.31 (95% Cl [-1.60; -1.02]). The effect size was very large (Cohen's $d = 1.21$), which confirms the strong impact of the didactic intervention on participants' sense of preparedness to introduce new technologies into educational classes (Figure 1).

Figure 1

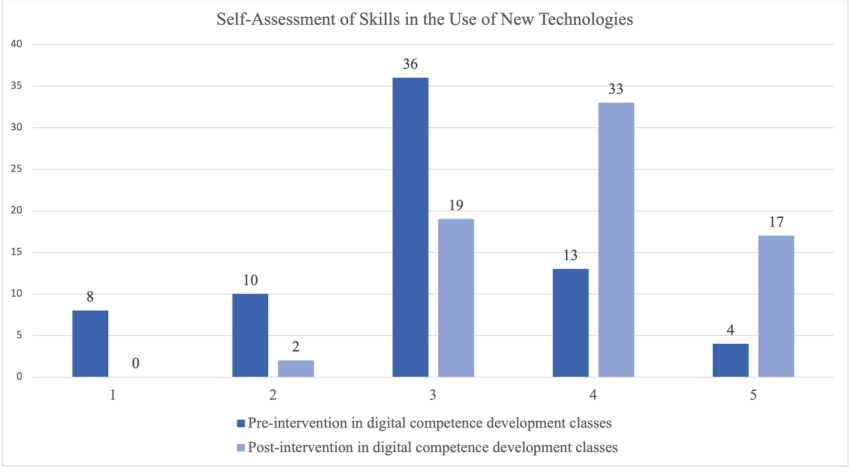
Students' Preparation for the Implementation of New Technologies in Educational Activities



The students also assessed their skills related to the use of new technologies. The mean score prior to the intervention was $M = 2.93$ ($SD = 1.00$), whereas after the intervention it increased to $M = 3.92$ ($SD = 0.79$). Analysis using Student's t-test for dependent samples demonstrated a statistically significant increase in the level of skills following the classes, $t(70) = -6.54$, $p < .001$, with a mean difference of -0.99 (95% Cl [-1.29; -0.69]). The calculated effect size was very large (Cohen's $d = 1.27$), indicating a strong impact of the conducted intervention on the development of the participants' technological competences (Figure 2).

Figure 2

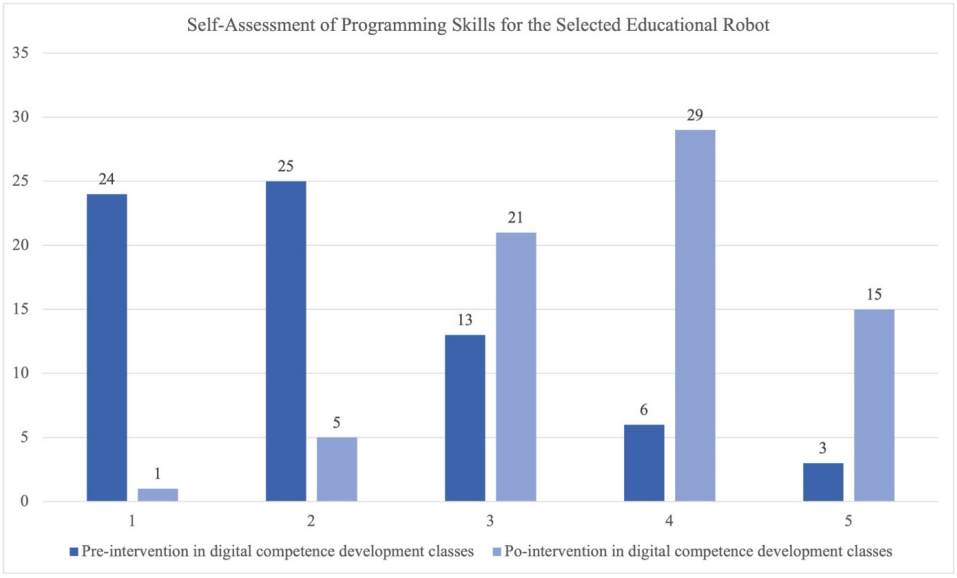
Self-Assessment of Skills in the Use of New Technologies



The mean level of programming skills in the examined group during the initial measurement was $M = 2.14$ ($SD = 1.11$), with the distribution of responses indicating a predominance of low ratings and a modal values of 2. After the classes, the students' self-assessment in the context of programming increased to $M = 3.73$ ($SD = 0.93$), with the most frequently indicated rating being 4, which reflects a high level of skills. Analysis using the paired-samples t-test demonstrated a statistically significant increase in the level of skills, $t(70) = -9.95$, $p < .001$, with a mean difference of -1.59 (95% Cl [-1.91; -1.27]). The effect size was very large (Cohen's $d = 1.35$), indicating a strong impact of the conducted classes on the increase in students' competences in programming the robot (Figure 3).

Figure 3

Self-Assessment of Programming Skills for the Selected Educational Robot

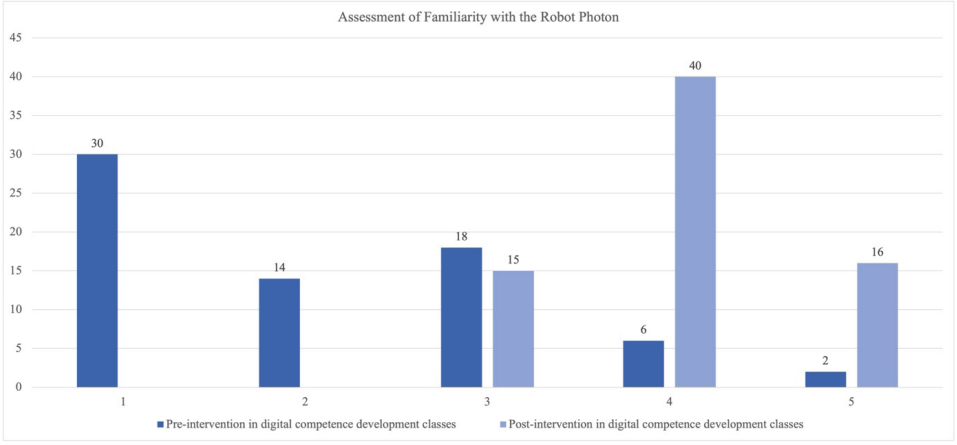


The figure (Figure 4) presents the distribution of self-assessed level of familiarity with the Photon robot before and after participation in classes supporting the development of digital competences. Prior to the didactic intervention, low ratings predominated, with level 1 indicated most frequently (30 respondents) and level 2 selected by 14 respondents. After the completion of the classes, a clear shift in the distribution towards higher values was observed. The most frequently chosen ratings were level 4 (40 respondents) and level 5 (16 respondents). The mean score before the classes was $M = 2.08$ ($SD = 1.13$), whereas after the classes it increased to $M = 4.01$ ($SD = 0.67$). Analysis using the paired samples t-test confirmed a statisti-

cally significant increase in the level of familiarity with the Photon robot, $t(70) = -11.39$, $p < .001$, with the mean difference of -1.93 (95% Cl [-2.27; -1.59]). The calculated effect size was very large (Cohen's $d = 1.43$), indicating a strong impact of the conducted didactic intervention on the increase in participants' knowledge regarding the Photon robot, including its application.

Figure 4

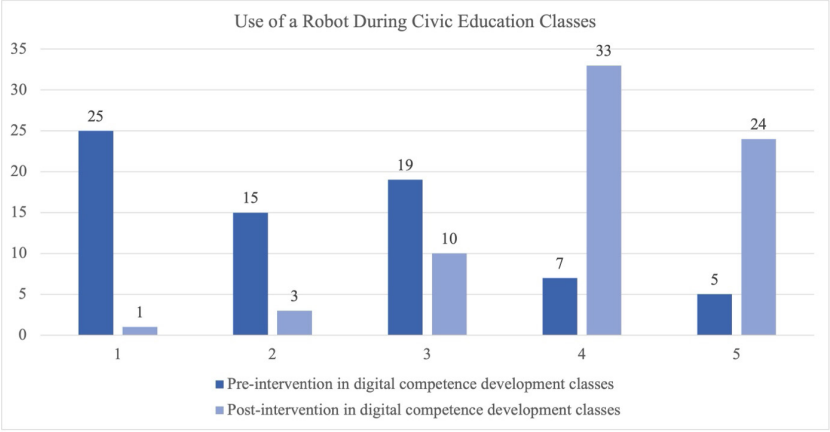
Assessment of Familiarity with the Robot Photon



In order to determine how to use of the robot during classes in the field of civic education was perceived, an assessment of the participants was conducted before and after their participation in the classes. The mean rating of the possibility of using the robot during civic education classes prior to the intervention was $M = 2.32$ ($SD = 1.25$); low ratings predominated, with level 1 indicated most frequently (25 respondents), followed by level 2 (16 respondents) and level 3 (19 respondents), which indicates a limited perception of the robot's potential application within this thematic area. After the classes, the mean rating of the robot's usefulness increased to $M = 4.07$ ($SD = 0.88$), and a clear shift in the distribution was observed. Analysis using the paired-samples *t*-test confirmed a statistically significant increase in the level of perceived possibilities for using the robot during civic education classes, $t(70) = -9.04$, $p < .001$, with a mean difference of -1.75 (95% Cl [-2.13; -1.36]). The effect size was exceptionally large (Cohen's $d = 1.63$), indicating a strong impact of the conducted didactic intervention (Figure 5).

Figure 5

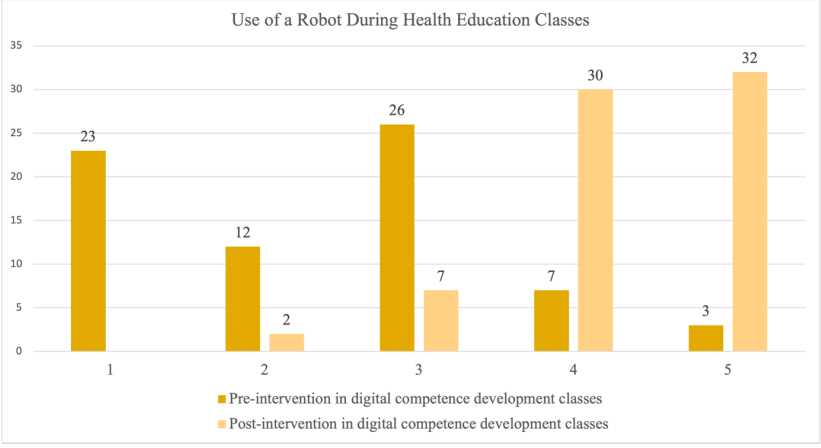
Use a Robot During Civic Education Classes



The same procedure was applied to examine the students' views regarding the possibility of using the robot in the field of health and environmental education. The mean rating prior to the classes was $M = 2.37$ ($SD = 1.16$), whereas after the classes it increased to $M = 4.30$ ($SD = 0.76$). Analysis using the paired-samples t-test confirmed a statistically significant increase in the level of perceived possibilities for using the robot when introducing topics related to health education, $t(70) = -10.12$, $p < .001$, with a mean difference of -1.93 (95% Cl [-2.31; -1.55]). The effect size was exceptionally large (Cohen's $d = 1.61$), indicating a very strong impact of the conducted didactic intervention (Figure 6).

Figure 6

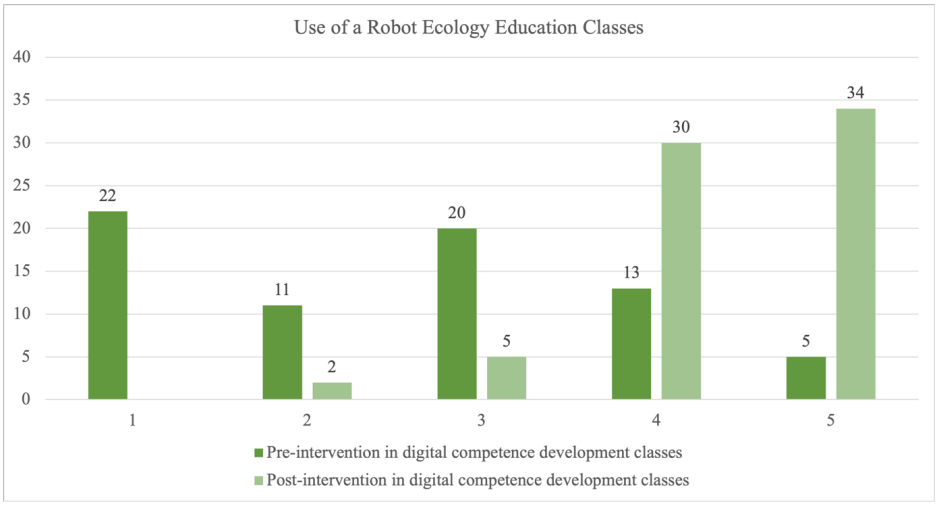
Use a Robot During Health Education Classes



At the initial measurement, the mean rating of the possibility of applying the robot to environmental topics was $M = 2.55$ ($SD = 0.74$). Analysis using the paired-samples t-test confirmed a statistically significant increase in the level of environmental competences, $t(70) = -9.10$, $p < .001$, with a mean difference of -1.80 (95% Cl [-2.20; -1.41]). The effect size was very large (Cohen's $d = 1.67$), indicating a very strong impact of the conducted didactic intervention (Figure 7).

Figure 7

Use of a Robot Ecology Education Classes

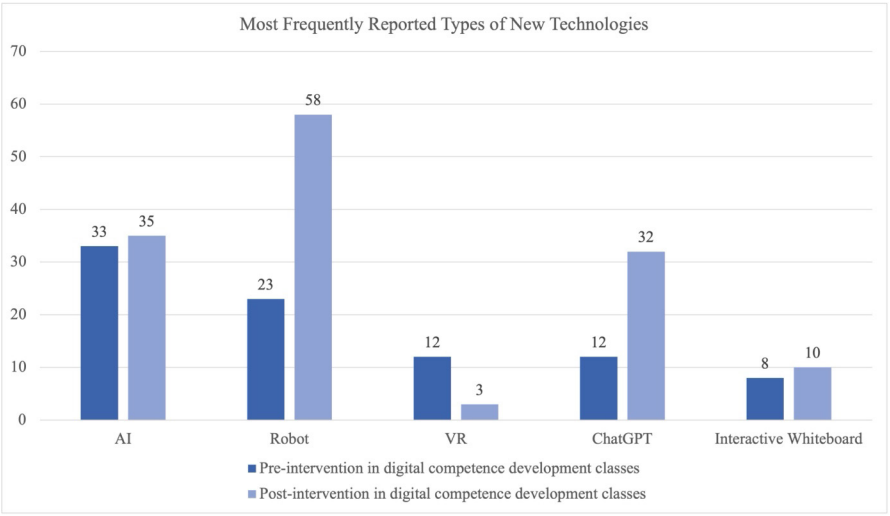


A comparison of both measurements regarding the possibility of using the robot in civic, health, and environmental education suggests that after the completion of the classes, the students more frequently recognised the robot's potential as a didactic tool. The change in the structure of responses indicates a transformation in the perception of the role of this type of technology in shaping civic, health, and environmental competences.

An analysis was also conducted of the types of new technologies indicated by the respondents. Prior to the didactic intervention, the most frequently mentioned tools were programmes using AI function, robots, VR devices, and ChatGPT. After the completion of the classes, a particularly noticeable increase in the number of indications concerning robots was observed, which suggests that the didactic intervention resulted in a change in the perception of the usefulness of robots in comparison with other types of new technologies (Figure 8).

Figure 8

Most Frequently Reported Types of New Technologies



Summary

The results of the didactic intervention conducted among the students, which encompassed both theory and practice in the context of the possibilities of using the Photon robot, demonstrated that the implemented intervention conditions the optimisation of digital competences among the students and also contributes to an increase in their readiness to use new technologies. Through becoming familiar with the functions of the device, the students broadened their understanding of its potential application and were prepared to develop their own educational materials in the form of lesson scenarios.

In conclusion, the student's readiness to introduce new technologies into educational classes increased, including classes devoted to environmental, civic, and health topics. The students' self-assessment improved in the context of their ability to use new technologies, as well as to programme the educational robot. The research revealed that the students were familiar with three educational robots: the Photon robot, the Ozobot robot, and LEGO bricks, as a compact device used for constructing and creating mechanised structures. The students most frequently identified contemporary new technologies as including artificial intelligence (AI) models, robots, VR, ChatGPT, and the interactive whiteboard.

Contemporary education increasingly bases its curriculum on the use of new technologies, which are becoming not only a support for the didactic process but also a significant element of teachers' professional competences. The dynamic development of digital

tools, including educational robots, requires students-future teachers-to demonstrate readiness for continuous learning and for adapting their skills to the changing needs of schools and pupils. In this context, particular importance is attached to the development of competences related to programming and digital hygiene, understood as the conscious use of technology in educational practice.

The conducted classes, during which students became acquainted with the possibilities of using the Photon educational robot and the basics of its programming, constituted an attempt to respond to these challenges. The obtained results demonstrated the validity of incorporating practical tools into the student training programme, which not only enrich the teaching process but also genuinely contribute to increasing students' digital competences, developing their imagination with regard to the use of new technologies and shaping positive attitudes towards their application in work with pupils.

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