The Effect of Teaching with Films on Prospective Teachers' Industry 4.0 Awareness

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Abstract

This research compared the effect of extracurricular activities, created from YouTube videos for the purpose of introducing new generation technologies, on prospective teachers' awareness of Industry 4.0 technologies. The research group consisted of last-year prospective teachers from Uşak University Faculty of Education in the spring semester of the 2024-2025 academic year. During the activity process, researchers showed videos introducing Industry 4.0 technologies to the prospective teachers in the experimental group for three weeks, on the same day and at the same hours after class. No extracurricular activities were conducted with the students in the control group. Before and after the video activities, the Industry 4.0 Technologies Awareness Scale was administered simultaneously to both the experimental and control groups. It was determined that there was no significant difference between the pre-test scores of the experimental group and the control group regarding Industry 4.0 technologies awareness. A significant increase was observed in the awareness test scores of the experimental group before and after the video activities. It was determined that there was no significant difference between the pre-test and post-test scores of the control group regarding Industry 4.0 awareness. It was determined that the experimental group showed a significant increase in post-test scores regarding awareness of new technologies compared to the control group.

Keywords: Industry 4.0, prospective teachers, films, youtube, awareness.

INTRODUCTION

In higher education, success isn't measured solely by standardized tests, but also by diverse skills like project literacy, technology literacy, and social media literacy. In the 21st century, universities are transforming from institutions that merely transfer knowledge and skills to students, into ones that drive the market. It's seen as necessary to provide students with competency and skill-oriented education instead of fixed-content curricula. Teachers are expected to lead students in enriching their learning paths rather than just transmitting information (Erkut, 2022). Among the new goals in higher education is the cultivation of individuals who can utilize new generation technologies and are lifelong learners (Çalık & Sezgin, 2005).

In the 21st century, the focus in higher education is shifting from merely transferring information to equipping students with skills for solving real-world problems, and this increasingly involves using new generation technologies. Universities are now aiming to foster problem-solving abilities and lifelong learning awareness in their students. Modern universities embrace a learning approach that is research-based, problem-solving oriented, and project and design-based. When it comes to assessment in higher education, in addition to standard achievement tests, methods like portfolios, student projects, observation forms, and online exams are gaining prominence (Trilling & Fadel, 2009). The World Economic Forum (WEF, 2024) emphasizes that the following technological competencies will be highly preferred in hiring in the new century: social media literacy, Industry 4.0 technologies literacy, and data analytics literacy. 21st-century skills encompass various characteristics that enable individuals to be good citizens and perform their duties effectively (Ayan, 2022). According to the OECD (2023), important 21st-century skills include the ability to collaborate, interact within groups, solve complex problems, and utilize new generation technological tools. Within the cognitive skills of the 21st century in higher education, effectively using Industry 4.0 tools is crucial (Akaltan, 2019). Updating higher education programs to include 21st-century skills and ensuring students acquire these skills plays a critical role in training qualified teachers. For academics to effectively impart these skills to students, they themselves must be proficient in using new generation technologies (Kurudayıoğlu & Soysal, 2019). New technologies are becoming an essential part of educational programs because current formal education programs in higher education systems are not focused on using new generation technologies. This process necessitates activity-based teaching programs (Eğmir & Erdem, 2021).

Developing new generation technology competencies is pushing higher education programs to create new content (Özgüner Kılıç, 2017). Among the priority competencies that prospective teachers should possess in the 21st century are critical thinking, problem-solving, and new generation technology literacy (Kalkan & Topçu, 2024). It's possible to raise awareness about Industry 4.0 technologies through low-cost video activities

Theoretical Framework

The Industry 2.0 era began with the development of mass production in the early 20th century. Ford's pioneering implementation of the assembly line system became widespread, leading to a new understanding of production (Bulut & Akçacı, 2017). The Second Industrial Revolution brought about faster production and higher quality final products. Factories now had the means and machinery to operate more extensively through automation. This also meant a reduction in the amount of work that needed to be done by humans (Carvalho, 2017).

The concept that brought Industry 3.0 to life was electronics. Rapid advancements in computers, and especially the internet, led to the information revolution being recognized as the Third Industrial Revolution. According to Schwab (2016), the third industrial revolution began in the 1960s, with the development of semiconductor technologies giving rise to microprocessor technologies. For this reason, the 3rd Industrial Revolution is also defined as the computer or digital revolution. Electronic technology, television, and automation technologies rapidly entered social life. In the mid-20th century, the acceleration of developments in heavy industry and information technology led to the emergence of a new term in the literature: the information society (Bulut & Akçacı, 2017). Towards the end of the Industry 3.0 period, computer technologies became integrated into every aspect of life, while processor speeds significantly increased. Robots, especially those used in mass production facilities, took on a larger role in production lines, and error-free, fast production began to develop (Genç, 2018). The ability to connect electronic and computer technologies to machines and to automate production systems, particularly the advancements in electronic, information, and communication technologies, increased automation in production, making it necessary for individuals to acquire new skills (Genç, 2018).

Industry 4.0 is built upon internet lines based on fiber optic technologies, microprocessors, and smart production technologies (Genç, 2018). New technologies have begun to offer consumers faster and more customer-centric product options (Carvalho, 2017). The digitalization evolving with technological innovation is shaping the future of higher education, in addition to various industries. New concepts have emerged in production, social life, and learning (Schwab, 2016). Key concepts related to Industry 4.0 include artificial intelligence, learning robots, cybersecurity, 3D printers, additive manufacturing, virtual reality, simulation technologies, and wearable technologies.

Artificial Intelligence (AI): The execution of behaviors by a machine that, if performed by a human, would be considered intelligent. AI aims to create systems that think and act like humans (Phan et al., 2018). *Learning Robots:* Robots that can collect data from their environment using sensors and perform certain artificial intelligence applications in their decision-making and action processes, due to embedded information technologies (Banger, 2018; Mourtzis et al., 2022). *Cybersecurity:* Encompasses the use of various tools and security approaches by organizations that utilize information and cyber technologies to protect their assets against all types of cyberattacks (Ünver, 2018). *3D Printers:* The process of producing a virtually designed 3D object by subjecting materials like polymer, composite, or resin to thermal or chemical processes (Kökhan & Özcan, 2018). *Additive Manufacturing:* Commonly used technologies in this production model include stereolithography, fused deposition modeling, 3D printing, selective laser sintering, selective laser melting, and electron beam melting (Özsoy & Duman, 2017). *Virtual Reality (VR):* A 3D simulation technology that uses various types of computers, a cabin, and special head-mounted displays to give people the sensation of being in a specific environment through the use of certain technologies (Kaleci, Tepe & Tüzün, 2017). *Simulation Technologies:* Enable the real-time operation of a factory or network and its control through simulation in computer environments (Eldem, 2017). *Sensors:* A type of sensory organ that provides data to the machines used in production (Berber, 2016). *Wearable Technologies:* Networked smart devices equipped with microchips, sensors, and wireless communication capabilities. Specifically, smart sensors placed on clothing, combined with wireless communication techniques, allow the garment to communicate with a mobile phone or another processor (Özgüner Kılıç, 2017).

Introducing new-generation technologies directly to younger generations in higher education, or creating awareness by having them directly experience these technologies, comes at a high cost. Therefore, remote learning applications are preferred for individuals to raise awareness more quickly and at a lower cost. Among these preferences, the increasingly popular video education (YouTube) applications are at the forefront.

The rapid development of digital technologies and the widespread adoption of the internet have brought about significant transformations in the field of education. Particularly, the proliferation of mobile devices and high-speed internet has made information more accessible. Alongside traditional teaching methods, digital educational materials have become a crucial part of the learning process. This transformation has led to radical changes in learning and teaching methodologies, increasing the speed at which students can access information (Bozkurt, et al., 2021).

Youtube is a platform where educational videos are uploaded in addition to entertainment videos. Youtube pays particular attention to education (Veblen, et.al., 2018). Youtube video application ranks first among the world's video applications. It is seen that there are thousands of educational videos related to different learning areas in this application (Gayretli, at.al., 2019). YouTube is recognized as the world's largest user-generated content publishing platform (Wattenhofer, et al., 2012). Offering a wide range of content in the field of education, YouTube has become an important resource for students to reinforce their course topics, learn new information, and prepare for exams. Especially during exam preparation, students benefit from various types of content such as lecture videos, problem-solving tutorials, and guidance videos related to different subjects. One of the reasons for YouTube's popularity is the diversity of content it offers and its ease of access. On this platform, students at every level can easily find content that suits their needs and access it whenever and wherever they want (Alp & Kaleci, 2018). YouTube videos, considered a part of the digital transformation in education, support students' independent learning processes and enable them to access information more quickly and effectively (Cihangir, 2021). Further research is expected regarding the increasingly widespread and preferred YouTube content and its effects.

Problem Statement

Industry 4.0 has brought about change in many sectors worldwide. This change is expected to reshape workforce skills, primarily in education and the business world (Penprase, 2018). Industry 4.0 has led to the emergence of the Education 4.0 process. Education 4.0 is seen as a new paradigm that fundamentally questions the concepts of learning, teachers, and schools (Himmetoğlu, et al., 2020). At the core of this innovation-based educational paradigm is individualized education. It is now accepted that the rote-learning, teacher-dictated instructional model is no longer effective. New skills, not seen in previous educational systems, have become necessary for individuals because Education 4.0 aims to train students as individuals who transform knowledge (Xing & Marwala, 2017). Here are the core assumptions related to Education 4.0, as outlined by Fisk (2017): Anytime, Anywhere Learning: Education can take place whenever and wherever desired. Individualized Learning: Personalized education should be prioritized and encouraged. Student Agency in Learning: Students should have the right to determine how they want to learn. This means they should be able to choose the learning tools and techniques they deem necessary for themselves. Project-Based Learning: Education should be predominantly project-based. Field Experience: Students should be provided with hands-on, practical field experience.

While there's a good amount of literature on Industry 4.0 itself, studies focusing on how Industry 4.0 and its components impact education appear to be less common. The existing research in this area often explores individuals' attitudes towards Industry 4.0 technologies, its effects on the education system, how it influences academic success, and the benefits and challenges it presents for schools. It also delves into its impact on native and foreign language acquisition, and the new meanings it brings to the concepts of "school" and "learning." (Oliveira & Souza, 2022 ; Kowang, et al.,2020 ; Cengiz, 2019 ; Adnan, et al., 2019 ; Yılmaz, et al., 2015; Tanrıöğen, 2018; Koç, 2018; Duisembekova, 2014 ; Keleşoğlu & Kalaycı, 2017; Saiful, 2019; Almurashi, 2016 ; Li, Gao, & Zhang, 2016). Other studies focusing directly on Industry 4.0 awareness have explored several key areas. These include: The impact of new technologies on learning and teaching methods in schools. Suggestions for overcoming political and bureaucratic obstacles to adopting new technologies. Which new skills are made essential by new technologies. The importance of providing in-service training for teachers to effectively use new technologies. The reasons that make learning new technologies difficult. Methods for disseminating next-generation technologies in schools (Butt, at al., 2020; Silva, et. al., 2021; Halili, 2019 ; Harkins, 2018; Dunwill, 2016). This research specifically compared the impact of extracurricular activities, designed using YouTube videos, on teacher candidates' awareness of Industry 4.0 technologies. This topic is particularly relevant as these technologies are considered key 21st-century competencies by the OECD (2023). This research data will provide evidence regarding whether video activities (from YouTube) have a direct impact on Industry 4.0 technology awareness. Here are the research questions addressed in this research:

- Is there a significant difference in the pre-test Industry 4.0 technology awareness scores between the experimental and control groups?
- Is there a significant difference in the Industry 4.0 technology awareness scores of the experimental group when comparing scores before and after the YouTube introductory videos?
- Is there a significant difference in the post-test Industry 4.0 technology awareness scores between the experimental group and the control group after the YouTube introductory videos?

METHOD

The research is an experimental study using quantitative research methods.

Research Design

This research employs a pre-test-post-test experimental design with a control group. In this type of research, groups are assigned proportionally based on various variables to ensure their comparability. Both a pre-test and a post-test are administered before and after the experimental intervention. This design is highly effective for determining cause-and-effect relationships. By comparing the changes in the experimental group (who receive the intervention) to those in the control group (who do not), researchers can more confidently attribute any observed differences to the intervention itself. (Aypay, 2022 ; Büyüköztürk, 2022). The research design is presented in Table 1. This table visually outlines the structure of the research, clearly showing how the experimental and control groups were formed, and at which stages the pre-test and post-test administrations took place.

Table 1. Research Design

Group	Pre-test	Youtube Video Screenings	Post-test
Experimental Group	✔	✔	✔
Control Group	✔	X	✔

In this research, two groups of teacher candidates were assigned: an experimental group and a control group. The experimental group received a pre-test and a post-test awareness scale both before and after extracurricular video screenings. The control group, on the other hand, was administered the pre-test and post-test awareness scales without any extracurricular activities.

Research Group

The research group of the research consisted of final-year prospective teachers at Uşak University Faculty of Education during the 2024-2025 academic year, Spring semester. To ensure equal group sizes, a final-year social studies teaching class of 25 students, with the same class size, was designated as the experimental group, and a final-year Turkish language teaching class of 25 students was designated as the control group. The experimental group comprised 15 female and 10 male students. The control group consisted of 14 female and 11 male students.

Data Collection Tool

To compare the Industry 4.0 technology awareness levels of the experimental and control group students, the researchers used a 14-item scale developed by Çağlıyan and Sakın (2023). This scale is three-dimensional, covering awareness in: Social life, work life, production Technologies. The scale's reliability and validity were thoroughly assessed. The Kaiser-Meyer-Olkin (KMO) value was determined to be .88, indicating good sampling adequacy. The internal consistency coefficient (Cronbach's Alpha) for all items was calculated as .902, which is well above the acceptable threshold of .70, demonstrating high reliability. Furthermore, a confirmatory factor analysis was conducted to verify the scale's validity. The results, including $\chi 2/sd=1.83$, NFI = 0.95, NNFI = 0.93, CFI = 0.93, IFI = 0.93, RFI = 0.93, GFI = 0.96, AGFI = 0.93, RMSEA = 0.05, and SRMR = 0.04, all met the criteria found in the relevant literature (Hair et al., 1998; Hoyle, 1995; Hu & Bentler, 1999; Kline, 2005), confirming the scale's high validity. The scale is a 5-point Likert-type scale, with the following average score ranges indicating different levels of awareness: 0 – 1.60: Not aware at all, 1.61 – 2.40: Not aware, 2.41 – 3.20: Partially aware, 3.21 – 4.00: Aware, 4.01 – 5.00: Fully aware.

Data Collection Process

The research began by administering a pre-test awareness scale for Industry 4.0 technologies to both the experimental group (25 individuals) and the control group (25 individuals). Following the pre-test, the researchers had the experimental group watch videos from YouTube related to new generation technologies. These video sessions were conducted as after-class activities for a duration of 3 weeks. The control group, however, did not participate in any extracurricular video activities. After the video activities concluded, both the experimental and control groups simultaneously took the post-test awareness scale for Industry 4.0 technologies. The specific content details of the video activities used in this research are presented in Table 2.

Table 2. Video Activities

	Industry 4. Technologies Presentation Videos (Youtube)	Video Link
Week 1 Wednesday/ Hours: 15.00- 17.00	1.Sensor Technologies	https://www.youtube.com/channel/UCndEWZCgWP0LatnqklhWo8A/about
	2.Drones	https://www.youtube.com/watch?v=qUmNqA8ks8c
	3.Wearable technologies	https://www.youtube.com/watch?v=TP4scGllK30
	4.Smart cities	https://www.youtube.com/watch?v=Q4_8tDT-_5k&t=87s
	5.Artificial intelligence	https://www.youtube.com/watch?v=D0NTkVrWG4Q&t=321s
	6.Biological warfare	https://www.youtube.com/watch?v=Q9DzXjINZ-0
Week 2 Wednesday/ Hours: 15.00- 17.00	7.Bitcoin	https://www.youtube.com/watch?v=3tKpB7jwwHE&t=176s
	8.Augmented Reality	https://www.youtube.com/watch?v=lqBbwGBm14U&t=222s
	9.Virtual Reality	https://www.youtube.com/watch?v=g1Mge0e8G98&t=2s
	10.Cybersecurity	https://www.youtube.com/watch?v=wSWlQVPzBrI
Week 3 Wednesday/ Hours: 15.00 - 17.00	11.Additive manufacturing technologies	https://www.youtube.com/watch?v=s63hf36nMcI&t=100s
	12.3D printers	https://www.youtube.com/watch?v=yIAlpXRSB8I&t=90s
	13.Simulation technologies	https://www.youtube.com/watch?v=deyL7t54wVg&t=7s
	14.Autonomous robots	https://www.youtube.com/watch?v=dqpr4o8Z4bM&t=610s

For three weeks, the experimental group watched a total of 14 videos (YouTube) related to Industry 4.0 technologies after their lessons, on the same day and at the same time each week. Of these videos six focused on the social life dimension of Industry 4.0 technologies (sensors, drones, wearable technologies, smart cities, artificial intelligence, biological warfare), four covered the work life dimension of Industry 4.0 technologies (Bitcoin, augmented reality, virtual reality, cybersecurity), four were related to the production dimension of Industry 4.0 technologies (additive manufacturing technologies, 3D printers, simulations, and autonomous robots).

Data Evaluation

Data from the Industry 4.0 Technologies Awareness Scale, administered as pre-test and post-test, were analyzed using SPSS 25. It was determined that the data showed normal distribution (Shapiro-Wilk: .201 > .05). The awareness scale data, administered as pre-test and post-test to the experimental and control groups, were analyzed using the "simple paired t-test."

RESULTS

The pre-test and post-test results for the experimental and control groups in the research are compared in Table 3, 4, 5, and 6.

Table 3. Pre-Test Results Of The Research Groups

Group	Industry 4.0 Technologies General Awareness Test	N	x̄	SS	t	P
Experimental Group	Pre-test	25	2.08	.556	.122	.904
Control Group	Post-test	25	2.05	.662		

$p > .05$

There was no significant difference ($p>.05$) between the pre-test scores on Industry 4.0 technologies awareness for the experimental group (composed of final-year social studies teaching students) and the control group (composed of final-year Turkish language teaching students). It was determined that the awareness levels of both groups regarding Industry 4.0 technologies were low ("I am not aware") prior to the research. Consequently, video viewing activities were implemented with the experimental group.

Table 4. Experimental Group Pre-Test Post-Test Industry 4.0 Technologies Awareness Levels

Industry 4.0 Technologies Awareness Levels	**N**	$\bar{x}$	**SS**	**t**	**p**
Pre-test	25	2.08	.559	1.38	***.002****
Post-test	25	3.02	.939		
Industry 4.0 Social Life Technologies Awareness Level	**N**	$\bar{x}$	**SS**	**t**	**p**
Pre-test	25	2.11	.692		
Post-test	25	2.46	.677	.598	.426
Industry 4.0 Work Life Technologies Awareness Level	**N**	$\bar{x}$	**SS**	**t**	**p**
Pre-test	25	2.25	.571	.585	.568
Post-test	25	2.59	.787		
Industry 4.0 Production Technologies Awareness Level	**N**	$\bar{x}$	**SS**	**t**	**p**
Pre-test	25	1.85	.594	2.30	***.003****
Post-test	25	2.98	.912		

$^{*}p< .05$

There's a significant difference (p<.05) between the pre- and post-test results for the social studies teaching final-year students in the experimental group after the video activities. Following the video activities, the experimental group's Industry 4.0 technologies awareness increased from a "not aware" level ($\bar{x}$:2.08) to a "partially aware" level ($\bar{x}$:3.02).

A significant difference (p<.05) was found between the pre-test and post-test awareness levels of the experimental group on the production technologies dimension of the Industry 4.0 scale. Following the video activities, the experimental group's awareness in the Industry 4.0 production technologies dimension increased from a "not aware" level ($\bar{x}$:1.85) to a "partially aware" level ($\bar{x}$:3.02). This dimension of the Industry 4.0 technologies scale includes additive manufacturing technologies, 3D printers, simulation technologies, and autonomous robots.

Table 5. Control Group Pre-Test Post-Test Industry 4.0 Technologies Awareness Levels

Industry 4.0 Technologies Awareness Levels	**N**	$\bar{x}$	**SS**	**t**	**p**
Pre-test	25	2.04	.639	.056	.559
Post-test	25	2.16	.552		
Industry 4.0 Social Life Technologies Awareness Level	**N**	$\bar{x}$	**SS**	**t**	**p**
Pre-test	25	2.11	.757	.058	.528
Post-test	25	2.24	.587		
Industry 4.0 Work Life Technologies Awareness Level	**N**	$\bar{x}$	**SS**	**t**	**p**
Pre-test	25	2.06	.758	.069	.517
Post-test	25	2.28	.596		
Industry 4.0 Production Technologies Awareness Level	**N**	$\bar{x}$	**SS**	**t**	**p**
Pre-test	25	1.91	.638	.071	.944
Post-test	25	1.93	.697		

p> .05

It was determined that there was no significant difference (p>.05) between the pre-test and post-test scores of the final-year Turkish language teaching students in the control group regarding Industry 4.0 technologies and their dimensions. At the beginning of the study, the control group's awareness on the Industry 4.0 technologies awareness scale pre-test was at a "not aware" level ($\bar{x}$:2.04). In the post-test awareness level ($\bar{x}$:2.16), no significant increase was observed.

Table 6. Post-Test Results Of The Research Groups

Group	Industry 4.0 Technologies Awareness Levels	N	x̄	SS	t	p
Experimental Group	Pre-test	25	3.07	.590	1.76	*.009**
Control Group	Post-test	25	2.04	.639		

**p< .05*

It was determined that there was a significant difference (p<.05) between the post-test scores concerning Industry 4.0 technologies awareness for the experimental and control groups after the video applications. Compared to the experimental group's Industry 4.0 technologies pre-test result ($\bar{x}$:3.07 / "not aware"), a significant increase was observed in their post-test scores ($\bar{x}$:3.07 / "partially aware").

It was determined that there was no significant increase in the control group's Industry 4.0 technologies awareness levels from the pre-test result ($\bar{x}$:2.05 / "not aware") to the post-test awareness level ($\bar{x}$:2.04 / "not aware").

CONCLUSION

In this research, a 25-student group of prospective teachers from the final year of social studies teaching watched 14 video films (YouTube) introducing Industry 4.0 technologies**.** These sessions took place outside of regular classes over three weeks**,** with three sessions in total. The 14 videos introduced 14 next-generation technologies featured in the Industry 4.0 scale and its dimensions, which were part of the study's data collection instrument. A control group of 25 final-year Turkish language teaching students from the same faculty, with the same class size.

At the outset of the research, it was determined that there was no significant difference (p>.05) between the pre-test scores of the experimental and control groups regarding their awareness of Industry 4.0 technologies. Both groups were initially at a "not aware" level concerning their knowledge of Industry 4.0 technologies.

A significant difference (p<.05) was found between the pre- and post-test results for the final-year social studies teaching students in the experimental group after the short video activities. Their awareness level was observed to have risen from "not aware" to "partially aware." Following the video activities, a significant increase in awareness levels was also determined among students in the experimental group concerning the Industry 4.0 production technologies dimension.

There was no significant difference (p>.05) found between the pre-test and post-test scores of the final-year Turkish language teaching students in the control group regarding Industry 4.0 technologies and their dimensions. The students in the control group only attended their regular lessons. This suggests that the undergraduate curriculum does not have content designed to increase awareness of Industry 4.0 technologies.

Following the video activities, a significant difference (p<.05) was observed in the post-test scores for Industry 4.0 technologies awareness between the experimental group and the control group (who only attended regular lessons). It was found that the experimental group students showed a significant increase in their Industry 4.0 technologies awareness levels in the post-test compared to their pre-test results. In contrast, the students in the control group did not exhibit a significant increase in their Industry 4.0 technologies awareness levels in the post-test compared to their pre-test results.

Various studies in the literature have yielded consistent results regarding the positive impact of YouTube on students' technology engagement and literacy: Students who effectively use YouTube channels have been found to have higher scores in technology literacy and social media literacy (Anderson, 2020). A positive correlation has been identified between university students' active use of YouTube channels and their inclination towards new interactive technologies (Luo, Zhang, & Qi, 2017). Students who utilize YouTube videos as course material have demonstrated a more positive attitude towards new technologies (Cihangir, 2021 ; Göklen, 2023). Using videos from YouTube as educational material has been shown to positively influence students' desire to access next-generation technologies (Alp & Kaleci, 2018). A significant relationship exists between students' ability to use the YouTube video archive and their interest in new technologies (Srinivasacharlu, 2020). Students who effectively use YouTube channels have been found to benefit more from new teaching technologies in problem-solving (Aruğaslan & Çivril, 2023; Alwehaibi, 2015). Science teacher candidates who frequently use YouTube channels for homework purposes have shown higher attitude scores towards technology-based curricula (Türköz, 2019).

In conclusion, within the context of this research's findings, the following recommendations have been developed:

Applied certificate training should be provided to pre-service teachers at university lifelong learning centers in the 21st century, aiming to equip them with the skills to effectively use Industry 4.0 technologies.

Universities should provide more support for projects aimed at utilizing Industry 4.0 technologies.
Higher education programs should include virtual-based courses designed to introduce Industry 4.0 technologies.

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