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Techno-philosophical and techno-pedagogical implications of a nonformal technology and design education model to empower youth: T3 foundation's DENEYAP technology workshops program

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Abstract
This mixed-methods analysis explores the DENEYAP Technology Workshops program, launched by the T3 Foundation in 2017, which aims to develop scientific thinking and problem solving at the intersection of teaching technology skills and design thinking among 4th- and 9th- graders through nonformal learning. The study sought to investigate the program's techno-philosophical and techno-pedagogical formation. Data collection involved qualitative interviews with founders ($n=20$) and program developers ($n=20$). Additionally, to provide a comprehensive understanding of the program from multiple perspectives, lesson plans ($n=11$) were analyzed to assess the curriculum, whereas classroom observations ($n=5$) offered insights into instructional methods and learner engagement. The findings obtained through theories such as technology, pedagogy and content knowledge; technology philosophy; and design thinking reveal that the harmony between leaders' and instructional teams' visions, and the presence of a solid techno-philosophy in a technology and design education program lead to considerable success; the program's collaboration with official and unofficial institutions provides incalculable benefits; empathizing (needs analysis) stage at design cycle is crucial and yields critical insights; and the program fosters interest and competency in techno-scientific thinking skills among learners. Conversely, indicating areas in need of improvement in the program, continuous trainer professional development is pivotal; infrastructure and material provision are essential, and there is a lack of quality assurance in assessment practices, in other words, the test stage at design cycle. This study of the innovative, practical and skills-based program points to the critical role of nonformal learning in preparing the next generation for a technology-driven future through the intersection of technology and design education immersed in a strong and rigorous techno-philosophical and techno-pedagogical design.

Keywords Technology education · Nonformal youth learning · Deneyap technology workshops · Techno-philosophy · Techno-pedagogy · T3 foundation

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Introduction

Children aged 10–15 require technology education to develop essential cognitive, creative, and digital competencies for contemporary society. Such education has been shown to enhance problem-solving, critical thinking, and creativity (Liu et al., 2023; Lewis, 2009), while also promoting digital literacy and online safety—skills that are crucial in an era of increasing digital engagement (Cowling et al., 2024). Technology-related skills are further associated with improved future employability (Shields & Behrman, 2000) and foster inventive thinking through hands-on activities such as coding (Murcia et al., 2024; Fleer, 1992). Moreover, technology education can empower young people to contribute to social change (Antoniou & Ioannou, 2018) and to participate actively in design processes (Druin et al., 2014), particularly when implemented through balanced and well-supported pedagogical approaches.

Technology education is not a dedicated component of the national school curriculum in Türkiye. To address this gap, the DENEYAP Technology Workshops (DYTWs), established in 2017 by the Turkish Technology Team Foundation (T3 Foundation), aim to advance the country's technological development by educating students in 4th and 9th grade, who are approximately 10 and 15 years of age, respectively. These workshops are implemented through a collaboration between the Turkish Ministry of Industry and Technology, the Turkish Ministry of Youth and Sports, the Scientific and Technological Research Council of Türkiye (TÜBİTAK), and the T3 Foundation, with an initial goal of establishing 100 DYTWs in 81 cities. The program supports the National Technology Initiative by providing both in-school and out-of-school learning opportunities. As of 2025, DYTWs had expanded to 139 centers, reaching a total of 3,500 students across 81 cities. The workshops focus on developing young people's scientific and technological thinking and problem-solving skills through a set of courses such as Advanced Technologies, Energy Technologies, Design and Production, Mobile Applications, Electronic Programming and IoT, Artificial Intelligence, Aerospace Technologies, Coding and Robotics, Nanotechnology, Materials Science, Software Technologies, and Cybersecurity.

Aligned with the goals of DYTWs, technology-oriented 21st-century skills encompass a broad set of knowledge, abilities, dispositions, values, and work habits that are critically important for success in education, contemporary careers, and the attainment of social status. These skills are defined in diverse ways, but typically include various forms of literacy (e.g., financial, scientific, numeracy, information and communication technology [ICT], and cultural and civic literacy); fundamental arithmetic and mathematical competencies; effective communication skills; and capacities such as creativity, collaboration, problem-solving, flexibility, leadership, and global awareness. Recent systematic literature reviews have identified seven core 21st-century skills with digital components: technical, information, communication, collaboration, creativity, critical thinking, and problem solving (Chen et al., 2023; Liu et al., 2024; van Laar et al., 2017).

In relation to these skills, adaptability to global technological advancements is crucial, as employers increasingly value not only academic achievement but also innovative individuals who can adjust to technological developments and provide leadership among their peers. For ongoing development, the ability to navigate new technologies, tools, and materials, to work effectively in diverse teams, and to engage in lifelong learning are key determinants of personal and professional success (Liu et al., 2024). These competencies form a multidimensional construct comprising knowledge, skills, and attitudes associated with higher-order abilities that enable individuals to cope with complex problems and unforeseen situations (Adıgüzel et al., 2023; Çetin & Çetin, 2021). Unlike formal classroom settings, informal and non-formal learning environments—such as makerspaces, technology education centers, and science workshops—provide students with contemporary, technology-focused opportunities that promote flexibility and autonomy in their learning pathways, foster intrinsic curiosity and constructive attitudes toward technology, and enhance motivation (De Loof et al., 2022; Walan & Gericke, 2023).

In line with the youth competencies identified as critical in the contemporary era, the purpose of this article is to examine the techno-philosophical and techno-pedagogical theoretical frameworks that inform and drive the DENEYAP Technology Workshops. These frameworks not only shape DENEYAP's pedagogical practices but also foster its technology philosophy, innovation, and ethical responsibility among young learners. The article seeks to identify the T3 Foundation leadership's techno-philosophical underpinnings and the program designers' techno-pedagogical approaches in DENEYAP by proposing a clear vision of what youth technology education should accomplish, and by outlining actionable strategies to overcome current barriers through a comprehensive and collaborative effort between formal and informal institutions to support DENEYAP. Specifically, the study addresses the following research questions:

- What are the foundational techno-philosophies and visions of the DYTW leadership team?
- What techno-pedagogical elements are incorporated into the DYTW program by the program developers?
- What comparative insights are evident in lesson plans on paper and lesson observations in practice?

Theoretical frameworks guiding the DENEYAP technology workshops

The DYTW program has been developed with a theoretical basis of models of design thinking, (Rowe, 1987), social learning theory (Bandura, 1977), and a philosophy of technology (de Vries, 2005). Prior to investigating the DYTW program, these frameworks are briefly introduced below.

Design thinking, a structured approach to design and innovation, emerged in the late 20th century and has since become integral to various fields, including technology education. Early proponents like Rowe (1987) defined design thinking as a creative and systematic problem-solving process that goes beyond aesthetics to encompass iterative learning and user-centered solutions. Owen (2007) further emphasized its flexibility, highlighting its applicability to complex, ambiguous problems often encountered in technology and education. This interdisciplinary methodology, combining logic, creativity, and empathy, is particularly suitable for technology education, where students need to integrate technical skills with real-world problem-solving. As Cross (2006) noted, design thinking is an evolving methodology, characterized by its iterative nature, where continual refinement and experimentation play key roles. This iterative process is essential in technology education, as students must test, fail, and improve their ideas through repeated cycles. The integration of design thinking into technology education promotes hands-on, experiential learning, as opposed to traditional rote memorization models. Romizsowski (2016) emphasizes that design thinking fosters active engagement, allowing students to tackle real-world problems and develop technical skills through direct interaction. Design thinking offers a rich context for researchers as it combines practices like user needs discovery, assumption challenging, ideation, and prototyping (Dell'Era et al., 2025; Zhang et al., 2024). In education, it enhances learning (Bales et al., 2024) and communication (Hawkins et al., 2024). It fosters interdisciplinary collaboration (Leem & Lee, 2024).

Bandura's social learning theory (1977) is another building block in nonformal learning environments where individuals inherently and intentionally develop skills and interact with and observe others. As alternative education settings heavily depend on social learning, the supportive argument is that outdoor, out-of-school, informal and nonformal learning environments allow for greater flexibility for hands-on learning, active learning, and learning by trial-and-error (Gross & Rutland, 2017). The related literature evolving around the investigation of the use of social learning theories in nonformal learning environments addresses different assertions because, in those environments, social negotiations of ideas compensate for knowledge building as a learning community, collaborate in the conventional exchange of ideas, and gain experience in pedagogical and subject-specific knowledge, skills and emotions within/between groups. In particular, the social negotiation of ideas is of utmost importance, as expressed by Benson et al. (2017).

With respect to the philosophical facet, de Vries (2005) was a source of insight and inspiration with his emphasis on a philosophy of technology. He emphasized in the book 'Teaching about technology' the importance of understanding the *philosophy of technology*, which is about exploring what technology is and why it matters, helps individuals gain insights into and appreciate the broader societal implications of technology itself and its impact on human life. Furthermore, artifacts resulting from technology and the ability to create and utilize these artifacts will ease the creation of new artifacts while also contributing to the understanding of the ones at hand (Dakers, 2006). To increase the efficiency and innovation of technological advancements, comprehending methods and procedures is critical, according to the author. Contemplating and considering the philosophical and practical relationship between technology and human nature is also highly valuable, as it shapes not only the surroundings but also individuals' behaviors, attitudes, and identities (Dow, 2005). Mitcham (1994) refers to this approach as the "humanities philosophy of technology" because it prioritizes the humanities over technology and aligns with the broader outlook of the humanities. Moreover, the ethical and aesthetical dimensions of technology are particularly critical in ensuring human well-being and environmental sustainability, such as in competitions and projects in DYTWs, if the functions and moral implications of technology (cybersecurity, digital literacy, and netiquette courses in DYTW workshops) are both taken into serious consideration. On the side of learners and teachers, there is a pivotal aspect of the philosophy of technology, which is teachers' support and encouragement for learners to develop their own philosophies of technology through critical thinking on the impacts of technology on their life and surroundings. In terms of the educational landscape in the philosophy of technology, what meets us is the role of education in reconceptualizing technology by incorporating philosophical underpinnings and perspectives into technology education. Finally, relative to practical issues in teaching about technology, the argument elaborates on the appropriate resources, techno-pedagogies, and a place reserved for techno-philosophical discussions in the curriculum. Taken together, these arguments, suggestions and offerings pave the path for DYTW program leaders, trainers, learners, the public, and all other stakeholders to make invaluable endeavors to develop their own philosophy of technology. To some extent, leaders, trainers, learners, the public, and other stakeholders have come together around the philosophy of the 'National Technology Initiative', which involves human well-being at first, global peace, environmental sustainability, several free nonformal workshops and training opportunities for all layers of society and mainly uprising youth, instructional materials and educational initiatives for all walks of life. As Keirl argues (2017), a well-designed Design and Technology (D&T) curriculum is essential for preparing students to become global citizens who can engage in democratic discussions about technological advancements.

Literature review

Led by the Republic of Türkiye and implemented in partnership with the Turkish Ministry of Industry and Technology, the Turkish Ministry of Youth and Sports, TÜBİTAK, and the Türkiye Technology Team Foundation, the National Technology Initiative aims to establish DYTWs in all 81 provinces of Türkiye and to cultivate individuals with advanced technology production skills. DYTW programs have been the subject of several academic studies (e.g., Eren & Dökme, 2022; Küreci & Bulunuz, 2020; Yılmaz & Fırat-Durdukoca, 2023; Temizhan et al., 2023). The scope of the present literature review is limited to studies that investigate the role of DYTWs in the development of 21st-century skills, scientific creativity, multifaceted thinking, and problem-solving. The following section discusses current issues more broadly in technology and design education, the philosophy of technology education, illustrative cases and challenges from technology education environments, and, finally, selected studies on the DYTW program.

Critical issues in technology education initiatives

Technology-based non-formal learning shares several similarities with formal learning, particularly in its emphasis on pedagogy and other central factors that are relevant across both formal and non-formal, as well as traditional and digital, learning contexts (Bulut et al., 2025; Karanfiloğlu & Bulut, 2025). In this regard, key emergent topics include collaboration among leaders, public institutions, and NGOs; questions of equity, access, and gender; pedagogical considerations; and the development of job-readiness and employment outcomes in non-formal technology education centers. Equally critical is the fact that formal technology curricula do not always exist at the national level (Livingstone et al., 2017; Vargas-Montoya et al., 2023), as appears to be the case in Türkiye. Although the integration of technology education into formal curricula is progressing slowly but steadily, significant challenges persist, particularly in aligning these curricula with local contexts and addressing disparities between developed and developing countries (Birgili et al., 2025; Su et al., 2023).

With respect to policy and employment readiness, Szpakowicz (2022) challenges the common assumption that technology skills are sufficient for securing employment, noting that such competencies have yet to gain widespread recognition and demand across many sectors. Consequently, young people trained in technological skills often encounter difficulties in obtaining job placements due to the limited level of technology adoption in broader labor markets. Conversely, and in line with EU policies that promote youth employability through ICT competencies and sustainability objectives, Picatoste et al. (2018) propose a new educational approach situated within non-formal learning frameworks, designed to enhance young people's employability by equipping them with essential technology skills. Furthermore, Shantini and Sudiapermana (2016) identify a lack of collaboration between public authorities and non-formal learning institutions as a major barrier to success, underscoring the need for greater public recognition and institutional support for these training centers. The critical importance of informal self-directed learning in the digital age is further emphasized by Nygren et al. (2019), who report that both formal and non-formal learning environments contribute to the development of advanced problem-solving skills in technology-rich contexts.

With respect to equity, access, and gender, Vermeire and van den Broeck (2024) examine how non-formal digital inclusion programs can help mitigate educational disparities among socially and digitally vulnerable youth. These programs aim to equip disadvantaged adolescents with tools for social learning, train youth workers in digital inclusion strategies, and engage a broader network of digital inclusion stakeholders. Gender-related issues are also central: Seraj et al. (2020), for example, investigate non-formal programming training for female sixth-grade students and report mixed attitudes toward the program, shaped in part by students' prior experiences. From a pedagogical perspective, Pienimäki et al. (2021) advocate the integration of playful elements into non-formal technology training for children to enhance motivation and social interaction. Similarly, Kariippanon et al. (2019) emphasize the benefits of flexible learning spaces that foster interaction and collaboration. Simpson et al. (2020) further demonstrate that exploratory trial methods in after-school tinkering programs can be more effective than traditional formal scientific approaches in promoting youth engagement in technology learning.

Overall, the literature highlights several key areas for further research, including policy-level collaboration, professional development for trainers, AI-enhanced lesson planning, equity and accessibility, gender equality, and alignment with labor market needs in non-formal technology education. Advancing these areas is critical for broadening the reach and enhancing the effectiveness of such programs.

Role of DYTWs in mastering Technology-Focused-21st century skills

Technology integration in Türkiye's K–12 curriculum continues to face significant challenges despite major initiatives and digital transformation projects led by the Ministry of National Education (Yilmaz, 2011; Akcaoglu et al., 2015). Key barriers include inadequate infrastructure (Akbaba-Altun, 2006), limited teacher training (Akcaoglu et al., 2015), and weak integration of technology into the curriculum (Schware & Jaramillo, 1998). Policy implementation has been inconsistent (Kurt, 2014), and there is a notable lack of systematic evaluation data (Soloway et al., 2001). Future success requires micro-level research and practice (Yilmaz, 2011), comprehensive teacher professional development, and stronger collaboration among stakeholders (Akkoyunlu, 2002). Addressing these gaps is essential for developing effective solutions, one of which is the design and implementation of informal technology curricula for Turkish youth, such as DENEYAP.

Yılmaz and Fırat-Durdukoca (2023) conducted a phenomenological study with 41 secondary school teachers, whose views indicated that they regard DYTWs as valuable learning environments that support various forms of learning for gifted students and enrich their multifaceted academic, social, emotional, and cognitive development. Temizhan et al. (2023) evaluated the initiative in relation to national and spiritual values that strengthen social bonds, awaken national sentiment, and shape societal life. This evaluation, designed as a qualitative case study, was carried out through semi-structured interviews with 40 middle school students in Ankara, the capital city of Türkiye. Using 26 codes grouped under four themes—national values, personal emotions, religious values, and improvement efforts—the researchers identified the following: (1) national values, including (a) independence, (b) love of country, and (c) love of the flag; (2) personal emotions, including (a) pride, (b) enthusiasm, and (c) diligence; and (3) religious values, including (a) awareness of values such as justice, (b) righteousness and loyalty, and (c) kindness. Overall, the initiative was found to contribute to the affective development of future generations in the context of both universal and national values.

DENEYAP technology workshops to promote scientific thinking and problem solving

Boeve-de Pauw et al. (2020) examined Sci-tech technology workshops with a focus on students' attitudes toward technology. The study involved 1,496 elementary school students who engaged with high-tech materials and exhibitions delivered via a mobile high-tech truck (the *Techno Trailer*) at their schools. The findings indicated that even brief STEM education programs (three weeks) can positively influence students' attitudes toward technology. In another study, Küreci and Bulunuz (2020) developed theory-based science experiments for students enrolled in DENEYAP Technology Workshops (DYTWs). These inquiry-based and discovery-oriented activities were implemented with 15 fourth-grade students at BİLSEM. The workshops encouraged learners to pursue their curiosity and make new discoveries, which they documented through writing, drawings, and verbal explanations. By connecting these experiences to real-life applications, the program fostered multidimensional thinking and product design skills. Data sources—including photographs, observation notes, and students' written work—showed that the workshops supported inquiry, experimentation, iterative trials, multidimensional thinking, discovery, and product design.

Çakır and Tüzün (2024) regard scientific creativity as a key component of 21st-century skills in the evaluation of students' scientific thinking. In their study, they employed a case study design with 21 gifted students attending DENEYAP Technology Workshops (DYTWs). Data were collected through a demographic questionnaire and a scientific creativity scale, and analyzed using content analysis. The findings indicated that students' scientific creativity levels were moderate. Moreover, a Kruskal–Wallis analysis showed that higher parental education levels were associated with higher levels of student creativity. Overall, the literature suggests a clear need for DENEYAP and points to several positive outcomes; however, it also underscores the need for more in-depth investigation into the program's underlying philosophy and pedagogical practices.

Methodology

Approach

This convergent mixed-methods study (Creswell & Plano-Clark, 2023) investigates the philosophical and pedagogical dimensions of DYTW, a non-formal technology education program designed to foster technology, design, and scientific thinking skills among youth. To this end, the study analyzes the program's philosophical underpinnings and instructional design through qualitative approaches involving program founders and program designers, as well as through the analysis of lesson plans and lesson observations. By employing a convergent mixed-methods approach (Cresswell & Plano-Clark, 2023), the research integrates distinct strands of data and rigorously thematizes them to provide a comprehensive and in-depth understanding of the program's overall efficacy and areas for improvement. For clarity, key terms are defined as follows: DYTW refers to the DENEYAP Technology Workshops, a three-year technology and design program; the T3 Foundation is the initiating body of this non-formal youth program. Sci-tech skills denote scientific thinking and technological abilities. *Leaders* are the founding figures responsible for articulating and guiding the program's philosophy, whereas *Program Developers* are PhD-level experts in program development, technology, and evaluation.

Context of the study: DENEYAP entry requirements and course organization

To date, 139 DYTW centers have been established across 81 cities. Each year, approximately 150,000 students in grades 4–5 and 8–9 apply to the DYTW program. Candidates participate in a two-phase examination process. The first phase is a computerized 40-item multiple-choice test covering mathematics, science, algorithms, and world culture. The second phase is a practical, hands-on assessment conducted before an expert jury, in which candidates are required to complete a final product by following a series of steps and combining a set of specified materials.

After being admitted to the 3-year DYTW program, as shown in Fig. 1, learners take 11 courses for 2 years and work on project completion in the 3rd year. With a total of 3,500 students having graduated from the program so far, the DYTW program offers the following courses, as displayed in Table 1:

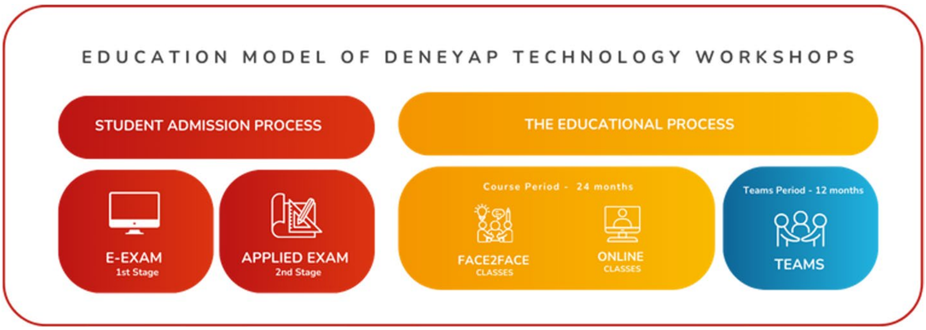

Fig. 1 Educational Model of Deneyap Technology Workshops (DYTW)

Table 1 DYTW Program Courses

Face to Face Courses	
Design and Production	The main purpose of the course is to acquire students with design-oriented creative thinking skills.
Coding and Robotics	In Robotic Coding training, students receive hands-on training on basic concepts of robotics, creating flowcharts, algorithms, gyro, decision structures, MicroPhyton.
Electronic Programming and Internet of Things	It is aimed to achieve the goal of providing students with the ability to produce algorithmic solutions to real-life problems obtained in Robotics and Coding training and to transfer them to the computer environment, and to produce solutions closer to real life with basic electrical-electronics and basic software knowledge.
Advanced Robotics	Students obtain general learning outcome such as robot types and their technological applications in industrial areas, choosing suitable sensors for the desired robotic application and applying basic signal processing methods by setting up a suitable hardware within the scope of this course.
Energy Technologies	Raising awareness about renewable energy sources and the reasons why are needed is the main purpose of this education.
Aerospace Technologies	The development of aviation industry from past to present in the world and our country, types of aerial vehicles and flight principles of basic aerial vehicles are taught in Aerospace Technologies training.
Nanotechnology and Materials Science	It is focused on how atomic structures of materials influence materials' mechanical, magnetic, optical and chemical properties within the scope of nanotechnology and materials science education.
Online Class Courses	
Cyber Security	It is aimed at teaching basic information suitable for student levels, raising awareness and acquiring some basic skills in order to ensure cyber security with this education program.Cyber Security training is taught online.
Mobile Application	Raising awareness about the access in the light of the concept of mobility by making applications about the control of the developed projects with mobile applications and the integrated working system with the Mobile Application education is aimed.
Artificial Intelligence	The aim of the training is to raise awareness about how artificial intelligence can be used in different fields, to create a vision for the future of this subject by making applications that are aiming to automate developed projects, and to lay the foundation for artificial intelligence if students want to specialize in this field.
Software Technologies	Students are taught basic programming logic, designing algorithms for problem solving and coding designed algorithms using C++ programming language in Software Technologies education.

Learners work in interactive and collaborative learning spaces as seen in Fig. 2. Gender balance is considered. Educators watch out and support self-regulated, autonomous learning, except in content delivery and guidance.

Data collection tools

Two interview protocols were created: one for founding leaders (RQ1), one for program designers (RQ2). Initially, two pilot interviews with DENEYAP founders and program designers were conducted and several refinements were made to the final interview protocol. Questions were reworded for clarity and specificity, and the sequence was reorganized to improve logical flow. Redundant items were removed, and probing questions were added to elicit deeper insights, particularly on curriculum design and instructional models. Technical terms such as “5E Model” and “4 C-ID” were clarified to ensure shared understanding. Additionally, the protocol was slightly adjusted to reflect varying roles of participants.

The final interview protocol directed to the founders was:

Fig. 2 Deneyap Technology Workshops in Labs and Spaces

Can you talk about the ***founding philosophy*** *of the DENEYAP workshops?*

Can you briefly describe the ***DENEYAP workshops****?*

What do you think is their ***goal and content****?*

How did you determine the ***course selection and sequencing****?*

It is observed that models such as the ***5E Model*** *and/or* ***4 C-ID*** *were used in preparing the course content. According to what criteria were these models chosen? Please explain.*

*In your opinion, how do DENEYAP workshops contribute to students' **scientific thinking** and **problem-solving skills**?*

*DENEYAP Technology Workshops aim to **contribute to the national and international development** and to raise youth who will **drive the National/Global Technology Initiative**.*

To what extent do you think this goal has been achieved so far?

The final interview protocol directed to the program designers was:

1. **Needs Analysis**

   How did you conduct the**needs analysis** while deciding on the program?

(Expert opinion, literature, examples of similar science center workshops globally, philosophy, societal needs, reports-documentaries-articles, etc.)
Can you talk about the**philosophy and foundation process** of DENEYAP workshops?
Can you briefly describe the **DENEYAP workshops**? What is their goal and content, in your opinion?

2. **Program Design & Planning**

After the needs analysis, what kind of design/plan/program was developed?
(Course subjects, number of hours, formation of weekly/monthly/yearly plans, etc.)
How did you decide on the**course selection and sequencing**? Can you provide detailed information?

3. **Content Development**

How was the process of developing materials, instructors, instructor training, resources, traditional/digital content, etc.?
It is observed that instructional models like the 5E Model and/or4C-ID were used in course design.
According to what criteria were these models selected? Please explain.

4. ***Implementation***

How was the implementation process, and what is the current state?
What are the positive aspects, and what are as need improvement or strengthening?

5. **Assessment & Impact**

How do you conduct the**assessment and evaluation** of the entire process?
What are the positive aspects and what could be improved?
How do you think the DENEYAP workshops contribute to students' scientific thinking and problem-solving skills?
DENEYAP aims to contribute to **Turkey's development** and to raise youth who will drive the ***National Technology Initiative***.
To what extent do you think this goal has been achieved so far?

Additionally, the validated 5E rubric (Goldston et al., 2013) was used to examine lesson plans (RQ3). This evidence-based instrument is particularly well suited to technology-enhanced non-formal learning environments and yields critical insights into instructional coherence and depth. To examine lessons in practice, a 5E rubric–based lesson observation form was also employed to observe and assess DYTW courses and workshops (Goldston et al., 2013) (RQ3). This form mirrored the phases of the 5E model, incorporating warm-up and triggering events; explanation, activity, and interaction; and feedback, evaluation, and reflection.

In addition to adopting the 5E framework, the program designers, through expert board discussions and panels, developed a locally grounded lesson-planning model specifically for DENEYAP, named GUTÜD. This model was piloted only in a limited number of lessons and was not implemented on a wider scale, primarily because the 5E lesson plan model was considered sufficient and more extensively validated in the academic literature. Nevertheless, it is worth noting GUTÜD as a locally devised master–apprentice instructional design model. DENEYAP's unique structure necessitated an innovative approach to module design, culminating in the creation of the GUTÜD model, which blends the traditional master–apprentice relationship with modern educational techniques to foster a deep, practice-oriented learning environment. The model consists of five structured stages: Observe (Gözlemle), Apply (Uygula), Design (Tasarla), Produce (Üret), and Evaluate (Değerlendir).

In a GUTÜD-led lesson, students are presented with a complex problem and are expected to apply what they have observed. They first develop a design and then move on to production. Working as a team, they reflect on the problem and create a draft solution, which may be imperfect but still progresses to the production phase. In the initial stage, the teacher answers students' questions and provides guidance; in the subsequent stage, students learn by doing (experiential learning). The primary goal is not necessarily for students to solve the problem correctly but to grapple with it, as this process develops their abstract thinking skills. They learn by attempting to resolve the errors they encounter and engage intensively with problem solving. They work collaboratively with peers, and components of computational thinking—alongside critical thinking and problem solving—are actively involved. As noted, however, GUTÜD remained too idealized to be used systematically for lesson and lesson-plan development and evaluation; consequently, the researchers relied on the 5E model, which is more globally recognized and empirically validated (Goldston et al., 2013).

Sampling and data collection sources

A convenience sampling method was adopted. Convenience sampling (Büyüköztürk et al., 2013) is appropriate when researchers seek the most practical, accessible, and feasible means of reaching participants and other data sources within close proximity. Accordingly, as shown in Fig. 1, data for the present study were collected from multiple sources, including leaders of the foundation ($n=20$; coded as Leader_1…Leader_20 in the findings) and program designers ($n=20$; coded as Program Designer_1…Program Designer_20 in the findings), who were consulted during the initial program design phase. In addition, lesson plans ($n=11$) and lesson observations ($n=5$) were incorporated as data sources.

Participants for both the leader interviews and the focus group discussions with program designers were recruited through convenience sampling, primarily via email invitations and phone calls. Participation was voluntary, and although the research team had prior professional familiarity with some individuals, this was limited and did not influence data collection. The selected participants represent a diverse and knowledgeable cross-section of DENEYAP's leadership and curriculum development teams, including those directly involved in strategic planning and instructional design.

For the selection of lesson plans and observations, a purposeful sampling strategy was employed to ensure coverage across different stages of the curriculum (e.g., beginner, intermediate, advanced modules) and key thematic areas (e.g., robotics, design thinking, coding). Lesson plans were chosen based on their use in the observed workshops to maintain alignment between the planned and enacted curriculum. The number of interviews, lesson plans ($n=11$), and observations ($n=5$) was determined by data saturation, with collection continuing until no new themes emerged and sufficient depth was achieved for thematic analysis.

The gender distribution of program founders was 62% male and 38% female. Regarding educational background, 36% of the founders hold a Bachelor's degree or higher, while the majority, 64%, have obtained a Master's or Doctorate. Professionally, the founders come from diverse backgrounds: 45% are engineers, 27% are academics, 18% are researchers, 9% are program developers, and a small percentage (1%) are entrepreneurs. In terms of work experience, 55% have 0–5 years of experience, 27% have 5–10 years, and 18% bring over 10 years of experience. This composition of gender, education, professional background, and experience suggests that the program founders are a relatively young and diverse group, with a strong technical and academic foundation.

The gender distribution of program developers was 58% male and 42% female. In terms of educational background, 47% of the developers hold a Bachelor's degree, while the remaining 53% have obtained a Master's or Doctorate, indicating a high level of academic qualification. Professionally, the developers come from diverse fields: 35% are educators, 25% are engineers, 20% are educational content developers, 15% are researchers (all with PhD level), and 5% are academic advisors (all with PhD level). Regarding work experience, 50% have 0–5 years of experience, 30% have 5–10 years, and 20% bring over 10 years of experience to the project. This mix of gender, education, professional background, and experience levels reflects a well-rounded and qualified group of individuals contributing to the program's development.

Data analysis

The collected data were subjected to both qualitative and quantitative analyses. For qualitative analysis, initial content analysis was conducted. This was applied to interview transcripts and observation notes to identify recurring themes and patterns. Next, thematic coding was administered through the data from interviews, surveys and observation forms. Quantitative data were extracted as descriptive statistics that were used to provide a numerical summary (Field, 2018). The following was a quantitative evaluation of lesson plans conducted via the 5E Model Rubric.

To achieve qualitative depth within the mixed methods framework, all stakeholder perspectives were initially categorized by role—namely, leaders, program designers, lesson plans, and lesson observations. Each data source was first analyzed independently through thematic analysis (see Supplementary Material 'SM1' for the full list of initial themes). Subsequently, overlapping themes across sources were identified and compared to highlight commonalities and contrasts. To further explore the instructional design principles of the program, two 2-hour focus group interviews were conducted with program design experts from TÜBİTAK (The Scientific and Technological Research Council of Turkey), the T3 Foundation, and university faculty in Information Technologies Education, Educational Technology, Curriculum Development, and Assessment. The focus group data were analyzed using deductive and axial coding in alignment with the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). Integration of the data occurred during the comparative phase, where themes emerging from individual analyses were synthesized to reveal cross-cutting insights. This approach allowed for both in-depth exploration within each stakeholder group and a comprehensive understanding through triangulation across data sources.

Validity and Reliability; Trustworthiness, Dependability, generalizability

To ensure the validity and reliability of the study, several measures were taken:

Triangulation: Multiple data sources and analysis methods were combined to corroborate findings and enhance credibility. *Member Checking*: Participants were involved in reviewing and validating the findings to ensure final accuracy. *Peer Review*: External experts were engaged in evaluating the research design, data collection instruments, and analysis processes. Expert opinions and peer reviews were utilized to ensure the reliability and validity of the qualitative data. By meticulously following these steps (Giddings & Grant, 2009), this research aimed to deliver robust and reliable insights into the effectiveness of the nonformal training program on technology and science skills for youth.

Findings

This section discusses the findings in line with the research questions presented in Table 2. In discussing the findings for the research questions, the researchers adopted a comparative, overlapping thematizing method. The comparative and overlapping findings are shown in Fig. 3. The research questions attempt to understand and propose the following:

Qualitative results

As seen in Fig. 3, common themes emerging from the qualitative inquiries are discussed in the following section. First, the theme is given. Then, the explanation is presented. Next, sample quotes are shared. Lastly, each theme is closed with a brief interpretation of the specific thematic finding.

Setting technology vision and philosophy

During the initial setup of the DYTW program, led by the leadership team, a clear technology vision and technology philosophy were set and disseminated at all levels of the program by all leaders, emphasizing their grounding in long-lasting civilizational sources as well as today's global peaceful and human-centered science-technology discourses. It included not only countrywide development but also a global movement of human-centered sci-tech. In evaluating national education and PISA-OECD reports, DYTW aimed at educating youth with 21 st century science, engineering and technology skills through project-based learning

Table 2 Research questions

RQs	Data Sources
RQ1	Founding Leaders' Techno-Philosophy and Vision
RQ2	Program Design(ers) (Design Thinking)
RQ3	Lesson Plans & Lesson Observations

Fig. 3 Common Themes

at Teknofest and other project festivals while also strengthening learners' social-emotional learning skills. Trainers were involved in the needs analysis stage, where leaders also transferred the vision and philosophy to the trainers to raise and foster youth with 21 st century skills and future-ready competencies, specifically sci-tech skills. The trainers were regularly informed that although logistical opportunities were limited at times, much effort was being made toward the vision and mission of the foundation and DYTWs. Young participants were also part of the vision and philosophy. Young participants in the DYTW program were given not only technical skill sets but also humane aspects and human dimensions of science and technology. Foundation's vision, passion and techno-philosophy were monumental gains for the DYTW program.

> Leader_2: Young people need to discover and develop their innovative and creative potential. The philosophy of not only consuming technology but also producing it is central to our approach. The core philosophy of DYTW is based on the vision of 'A Turkey that Produces Technology.' (Program leaders, interviews).

> Leader_8: If we are developing technology, it is essential to instill in our young students the idea that this technology should primarily benefit our own country but ultimately be used for the good of the entire world. (Program leaders, interviews)

> Program Designer_8: We are producing a generation that is interested in technology and solves technological problems, thinking in a design-oriented manner from the beginning of the course. They create human-centered solutions, observe problems, and try to solve those problems to the best of their knowledge. (Trainers, focus group interviews)

The DYTW program emphasized a clear technology vision and philosophy grounded in both civilizational values and global human-centered science-technology discourses. Program leaders and program designers instilled a vision of youth not only consuming but producing technology, aiming to foster innovation, design-oriented thinking, and social-emotional skills while promoting technology that benefits both local and global communities.

Collaborative work leads to a large scale technology education ecosystem: dytw's birth

The priority in the analysis (needs analysis, learner analysis, context analysis, material analysis, technology and infrastructure analysis) for developing the DYTW program was selecting and appointing program designers (curriculum developers) experienced in nonformal learning, out-of-school learning, and science and technology education studies. Hence, researchers with Ph.D. in these areas were offered and selected by TÜBİTAK.

According to the two program designers responsible for developing 11 course modules, managing this process required experienced professionals in the field. Recognizing this necessity, TÜBİTAK (The Scientific and Technological Research Council of Turkiye) selected two experts with Ph.D. qualifications in nonformal learning, out-of-school learning, and science and technology studies. These specialists emphasized that the DYTW program's development began with a comprehensive analysis phase, which included needs analysis, learner analysis, context analysis, material analysis, and technology and infrastructure analysis, ensuring a solid foundation for the program.

The theme emphasized the crucial role of the T3 Foundation's partnership, sustained support and collaboration with scholars, public institutions and NGOs in conducting a thorough needs analysis. Step-by-step progress was made with the approval of the leadership team, who were the pioneers and initial implementers of the DYTW program. This means that the leaders were involved not only in the analysis and design stage but also in all the following phases. During the needs analysis phase, a literature review, the age appropriateness of the target group, expert interviews, and an analysis of global good practices in informal and nonformal projects were conducted. Moreover, available research studies on DYTW and the global literature on nonformal learning programs were examined. Professionals with practical experience in nonformal science learning enriched the program through scholarly perspectives. Many good people were involved in the process of success, and program developers stated that DYTW's implementation process involved excessive work and performance and that what was needed the most was further passionate team members. Researchers and field experts have collaborated on module designs and sought ideas and contributions from a diverse range of stakeholders to enhance field applicability. This collaborative success was reflected on the learner side as well. Learners' feelings of satisfaction, the prevalence of hands-on active learning opportunities throughout the program, assessment opportunities at project festivals, and joining international projects at the end of the DYTW program caused joy and interest in learners. The DYTW program was shaped with invaluable contributions from public institutions and NGOs. The Ministry of Youth and Sports, the Ministry of Industry and Technology, the Scientific and Technological Research Institution of Turkiye (TÜBİTAK) and several municipalities played crucial roles in accomplishing success in the DYTW program. In brief, well-planned collaboration among several key organizations could be said to be a milestone in managing nonformal learning environments.

A significant finding on the other side of the medallion was the implementation, which was the actual practical phase. The plans that were discussed at the analysis, design and development stages encountered shortcomings at the implementation stage. Successful practices were sure to exist, yet difficulty emerged in transferring what was intended on the paper plan to the actual practice. For example, when determining age-appropriate learning outcomes, materials and activities prevail as a source of disagreement among stakeholders, particularly at the needs analysis stage. Furthermore, implementing the same DYTW program across 81 provinces, which could be categorized as developed, developing and underdeveloped cities, bore risks due to gaps in educational disparities. Applying the same nonformal learning program across the country required customized training-trainer sessions, additional student support and material, and continuous socioacademic guidance. Additionally, financial needs, time constraints, outdated technological hardware and software in classes, lack of a meticulously prepared yearly schedule and agile management responsiveness were areas for improvement.

Leader_5: *In these workshops, it was actually thought to cooperate with municipalities. It was realized that there were already various centers of the state that were idle, and at this point, the idea was proposed that a transformation could be made to use those centers more efficiently.* [Collaborative Work] (Program leaders, interviews).

Leader_1: *Due to both the difficulty of writing the content by students and the idea that this work could not be spread locally with only one municipality in Istanbul, this turned into a state decision, and a decision was made to establish 100 DYTWs in 81 provinces as an item in the presidential 100-day action plan. In this context, since it would not be possible to carry out such large-scale work only by the T3 Foundation and because it was transferred to the state, the ministry process was started. In this context, a quadruple protocol was signed as the Ministry of Industry and Technology, T3 Foundation, TÜBİTAK, and GSB, and the areas of authority and responsibility of each institution were determined by a protocol.* [Collaborative Work] (Program leaders, interviews).

Program Designer_4: *In each module, there were at least two or three people, and we were moderating..."We worked with maybe 10–15 people. Meetings were held.* [Teams] [Expert Opinion] (Program designers, focus group interviews).

Program Designer_11: *Speaking a common language was initially very difficult. It was very new for everyone, which made reaching a common language challenging.* [Disagreement] (Program designers, focus group interviews).

Program Designer_8: *Colleagues from the T3 Foundation, the Ministry of Industry and Technology, and the Ministry of Youth and Sports were also involved, etc."* [Stakeholder] (Program designers, focus group interviews).

Program Designer_17: *A large amount of feedback was collected during this process, but we could not allocate the necessary time for their evaluation and publication."* [Time challenges] (Program designers, focus group interviews).

The DYTW program's development relied on extensive collaboration between TÜBİTAK, public institutions, and NGOs. A comprehensive needs, learner, context, material, and infrastructure analysis phase laid the foundation for the program's design. Despite challenges in implementing a standardized approach across diverse regions with varying educational resources, the collaborative approach ensured the program's adaptability. Key challenges included disagreements over age-appropriate materials, technological limitations, and financial constraints. However, the decision to scale the program nationally, supported by a quadruple protocol between key stakeholders, ultimately led to success. The partnership-driven model highlighted the importance of continued collaboration for scaling nonformal technology education.

A unique instructional design model in technology and design education

The program developers designed a curriculum with 11 modules, where the subjects and project development processes were structured in a spiral manner. The courses included "Design and Production," "Robotics and Coding," "Electronic Programming and Internet of Things," "Advanced Robotics," "Cyber Security," "Energy Technologies," "Aerospace Technologies," "Software Technologies," "Material Science and Nanotechnology," "Mobile Application" and "Artificial Intelligence". The spiral curriculum was intended to provide learners with innovative sci-tech skills in a sequential and complementary fashion. In addition to the 5E lesson planning model, DYTW's unique program structure necessitated an innovative approach to lesson plan design, culminating in the creation of the 'GUTÜD model.' This model innovatively blends the traditional master-apprentice relationship with modern educational techniques, fostering a deep, practical learning environment. Its structural stages are observe, apply, design, produce, and evaluate, which are different from those of the 5E model (engage, explore, explain, elaborate, evaluate). The DYTW program ensured that participant learners would gain the predetermined goals and learning outcomes of the program to achieve the youths' acquisition of sci-tech skills.

> Program Designer_18: *We paid special attention to following a spiral curriculum. For example, as mentioned, design and production initially appeared in different formats. We posed questions such as how a child can transform a product into a project, how a product can be turned into reality, followed by how it is coded, how the electronics are done, and finally, how the software is developed."* [Spiral Curriculum] (Program designers, focus group interviews).

> Program Designer_7: *There is an emphasis on design thinking. For instance, "Let's empathize now. What do you need to design? We can go back. We made the prototype, but we can go back and think again. We can correct our mistakes.* [Design Thinking] (Program designers, focus group interviews).

> Program Designer_6: *Three courses stand out: design thinking, robotic coding, and electronic programming. It was thought that students enrolled in these courses would likely produce more outputs in other subjects."* [Basic 3 Modules] (Program designers, focus group interviews).

Program Designer_19: *I particularly find the initial lessons in design, robotics, and electronics very successful in terms of their practical aspects. I believe that these first lessons are carefully prepared, focusing on the subject, and the workshop facilities are provided very well."* [Basic 3 Modules] (Program designers, focus group interviews).

The DYTW program developed a unique curriculum with 11 modules, organized in a spiral structure to provide innovative sci-tech skills in a sequential and complementary manner. Modules like "Robotics and Coding" and "Artificial Intelligence" aimed to enhance students' skills progressively. In addition to the 5E lesson model, the program introduced the 'GUTÜD model,' which combines the traditional master-apprentice method with modern educational techniques. This model's stages—observe, apply, design, produce, and evaluate—differ from the 5E model's stages. Emphasizing design thinking, the program aimed to foster a practical learning environment and ensure students' achievement of key sci-tech competencies.

Active learning environments for technology skills

With rigorous communication, partnership and collaboration with official bodies and NGOs, the DYTW program hosted rich learning experiences ranging from learning environments and digital and conventional learning materials to project competitions. The program was designed with the involvement of trainers to gather their perspectives and experiences in teaching scientific thinking and technology skills. Trainers constantly designed and delivered active learning pedagogies and hands-on practice, and if necessary, they prepared additional materials on the basis of dynamic student needs. As the program aimed at the outset, cognitive benefits, such as scientific thinking, problem solving and technology skills, were abundant.

Conversely, there were times when learners expressed dissatisfaction with a few courses where they claimed that active learning techniques were not utilized. The trainers were well aware of the contribution of active learning and emphasized its impact on enhancing learner motivation and interaction. They underlined the necessity of using rich materials to support active learning. Finally, the need for continuous training-trainer sessions was emphasized, including active learning pedagogy, the use of online/virtual tools, instructional technology and material design, motivational aspects, how to take attendance, follow-up and feedback strategies, and effective learning approaches.

Program Designer_20: *When we get students to focus on a specific example or a theme in design and robotics, especially in bus and training examples, they brainstorm so much with the team to avoid making the same thing as each other. I think this enhances their cognitive thinking skills.* [Problem Solving, Cognitive Thinking] (Program Designers, focus group interviews).

Program Designer_6: *In DYTWs, especially with Teknofest, we believe that even middle school children can make their own drones, rockets, and missiles.* [Tech Innovation Motivation] (Program Designers, focus group interviews).

The DYTW program created active learning environments through strong partnerships with official bodies and NGOs, offering rich learning experiences using both digital and conventional materials, along with project competitions. Trainers actively incorporated feedback and designed hands-on pedagogies to foster scientific thinking, problem-solving, and technology skills. However, some learners expressed dissatisfaction when certain courses lacked active learning techniques. Trainers emphasized the importance of these methods in enhancing motivation and interaction, and stressed the need for continuous training in areas like instructional technology, material design, and feedback strategies. The program also highlighted how projects like Teknofest motivated students toward technological innovation.

Lesson plans and observations: an apple never falls far from a tree

The lesson plans were prepared by expert researchers with Ph.D.s in education sciences. When appropriate, the lesson plans followed the 5E model. In some cases where the subject/content was not conducive, the GUTÜD model was utilized. This was an opportunity for pilot testing the DYTW-special GUTÜD lesson planning model. What is stated in lesson plans and what is witnessed in lesson observations might involve similarities as well as differences. Hereby, the feature similarities are discussed.

Diversity and interaction in learning techniques At the beginning of the lessons, question-answer and brainstorming techniques were employed to encourage active participation among students. Learning objectives were clearly defined, and the use of visual and auditory stimuli created an engaging learning environment. For example, students researched piezoelectric materials via computers during class, working in groups and sharing their findings with classmates.

Practical applications The practical experiments included in the plan positively contributed to the learning process. During an observed lesson, three activities were conducted. The “How Fluorescent Lamps Work” activity garnered significant interest from the students.

Technology and everyday life connection The teacher concretized the topics by incorporating examples related to everyday life, such as high-speed trains, credit cards, and contact lenses, into the lesson plans.

No (Lesson) plan fully survives: as opposed to what it seems like on the blueprint

Here, differences in written lesson plans and actual lesson observations are discussed.

Lack of materials The strong materials mentioned in the textbooks were not adequately provided in the classroom, leading to disruptions in lesson delivery. For example, the activity “Examining the Basic Electrical Properties of Materials” involving various metal plates could not be conducted due to material shortages.

Information overload The teacher directly taught from the textbook. The textbooks, which are designed to provide comprehensive content while considering differences in teacher quality, create an information overload that is unnecessary for learners, leading to a loss of interest. For example, in sections covering topics such as "Generation and Transmission of Electrical Energy" and "Atomic Structure and Charged Bodies," the teacher monotonously read from the book, skipped some pages without discussion, and did not explain fundamental scientific concepts.

Information-Dense areas These were some sections where learners most frequently disengaged. Such information density negatively affected the efficiency of the lessons, with learner engagement in these sections dropping to an observed state of passive delivery.

Time constraints Due to changes in DYTW's annual calendar, the observed lesson had to be condensed. The shorter duration than ideal led to the omission of essential lesson components, such as discussing experimental results and assessment and evaluation sections.

Safety symbols and directives The absence of safety symbols and explanations in the textbooks led to serious issues in practice. In particular, in chemical experiments, learners encounter accidents; these experiments are conducted in inappropriate classroom settings. For example, during an experiment investigating specific heat differences, an accident occurred due to insufficient safety measures while an alcohol burner was used. These practices, which do not comply with occupational health and safety procedures, increase risks.

Incorrect information Although at minimal levels, textbooks contain incorrect information about the conductivity levels of materials such as gold and copper, which mislead the learners in the class. Both educators and learners noticed this error, which diminished the reliability of the lesson and materials.

Motivation down, drop-out up

The program included hybrid formats for some classes. This led to inefficiencies in learning and teaching processes in some courses. Apart from the online mode's inefficiencies, fluctuations in learners' motivation due to unclear scheduling problems (unclear or unannounced changes in programs), national high school or university entrance exam preparations (formal schooling exams that are deemed more important than unrecognized nonformal learning due to socio-educational habits) and sometimes family pressures on children to attend classes and workshops have occurred. Dropouts were observed when comparing the course-outset and course-end attendance rates.

The program included hybrid formats for some classes, which led to inefficiencies in learning and teaching processes in certain courses. Both teachers and students highlighted issues during the focus group discussions. Teachers emphasized fluctuations in learners' motivation caused by the preparation period for national high school or university entrance exams (prioritized over nonformal learning due to socio-educational habits), family pressures on children to attend classes and workshops, and the significant difference in participation between face-to-face and online lessons. They noted that unclear scheduling problems (such as unannounced or unclear program changes) also contributed to these challenges. Students, on the other hand, underlined that scheduling inconsistencies disrupted the seriousness of the program and suggested that adhering to fixed dates would improve its structure. They also highlighted that high school exam periods often conflicted with program schedules, leading to reduced participation during those times. Additionally, both groups pointed to dropouts, as evidenced by the significant decline in attendance rates from the beginning to the end of the courses.

> Program Designer_4: *Regarding the lessons*, *we realized that Deneyap students struggle and have low motivation during the preparation period for high school and university entrance exams. Their schedules are very intense. There are classes that start with 20 students and end with only 4.* [Exam Preparation Challenges] (Program Designers, focus group interviews).

> Program Designer_15: *There is a significant difference in participation between face-to-face and online lessons. I can clearly see in my classes that the success I achieve in face-to-face lessons is not mirrored online.* [Low Participation in Online Classes] (Program Designers, focus group interviews).

The DYTW program faced challenges with hybrid learning formats, leading to inefficiencies in some courses. Fluctuations in student motivation were influenced by unclear scheduling, national exam preparations, and family pressures, with students often prioritizing formal education over nonformal learning. Both teachers and students noted discrepancies in participation between face-to-face and online classes, contributing to higher dropout rates. Teachers observed significant motivation drops during high school and university entrance exam periods, with attendance decreasing dramatically from course start to end. Students emphasized the importance of consistent scheduling, while trainers acknowledged the low participation in online lessons compared to in-person sessions.

How to (what extent) enrichingly assess the nonformal

Assessing and evaluating a field-based nonformal learning program in 81 provinces brought good practices and challenges together. This has led program designers and other stakeholders to devise enriched, diverse assessment methods such as field observations, project rubrics, self-evaluation rubrics, learner evaluation forms, scales and local reports. An interesting finding is that learners enjoy a competitive learning environment. They wanted to be assessed not only with their classmates but also with all other learners enrolled in the program, such as a hackathon or a project competition.

> Program Designer_13: *Our planning also included project festivals. All the modules were designed around project-based activities.* [Project Festivals] (Program designers, focus group interviews).

> Learner_9: *The absence of a pass/fail system also provided great comfort. That is why we approached the (project festival) competition with a learning mindset."* [Assessment through Project Festivals] (Program designers, focus group interviews).

Assessing the DYTW program across 81 provinces involved both good practices and challenges, leading to the development of diverse assessment methods like field observations, project rubrics, self-evaluations, and learner feedback forms. Learners enjoyed competitive environments, preferring assessments that included hackathons or project festivals, which fostered a learning mindset.

A hidden curriculum as an eye opener: fueling learners' career path & Socio-academic endeavor

DYTWs resulted in shaping, reshaping and influencing the participants' career plans. While reinforcing some children's predetermined career goals in DYTW-relevant fields, the program also altered some other learners' plans, for example, from medical studies to engineering areas.

The DYTW was not designed as a pure sci-tech skills heavy program. Instead, it included socioacademic skills and 21 st century skills such as teamwork, collaboration, social-emotional learning, and human-centered technology.

> Leader_6: *"Students between the ages of 10 and 17 start thinking about their future careers. At this age, providing education in technology can increase their awareness of careers based on technology and influence their decision to pursue technology-focused careers.* [Career path] (Program leaders, focus group interviews).

> Program Designer_15: *In Phase 1, nearly all the students who came wanted to go to medical school or were students in the Faculty of Science. Nine to ten of our students from DYTW have chosen to join engineering faculties.* [Career path] (Program Designers, focus group interviews).

> Leader_3: *We first organized Teknofest in 2018. During this 1-year period, our students received training. Even in the first year, students participate in the technique. We had students who were both finalists and ranked highly.* [Competitions] (Program leaders, focus group interviews).

The DYTW program influenced participants' career paths, reinforcing some learners' existing goals while redirecting others, such as from medical fields to engineering. Beyond technical skills, the program also emphasized socio-academic and 21st-century skills like teamwork, collaboration, and social-emotional learning. Leaders and designers noted that early exposure to technology raised career awareness, with many students choosing engineering over other fields, particularly after participating in events like Teknofest.

Quantitative results

Quantitative scoring of the lesson plans

The DYTW program had lesson plans (n = 113) for 11 courses. To examine the direction of the lesson plans in the program, approximately 10% of all the lesson plans (n=11) were randomly selected, as displayed in Table 3, and analyzed by three researchers with Ph.D.s. Their expertise is science education, biology education, and educational sciences. The 5E

Table 3 Lesson observation plans

Week	Hours per Week	Subject	Lesson Plan Model(s)	Grade Level
8	4	Renewable Energy: Wind technologies	5 E Instructional Model (Engage-Explore-Explain-Elaborate-Evaluate)	4th grade
5	4	Aviation and Space (Deneyap Model): Avionic systems	DYTW GUTÜD Model (Observe, Apply, Design, Produce and Evaluate)	4th grade
5	4	Materials Science and Nanotechnology: Electrical properties of materials*	5 E Instructional Model	4th grade
6	4	Materials Science and Nanotechnology: Thermal properties of materials	5 E Instructional Model	4th grade
7	4	Materials Science and Nanotechnology: Magnetic properties of materials	5 E Instructional Model	4th grade
8	4	Materials Science and Nanotechnology: Optical properties of materials	5 E Instructional Model	4th grade
3	4	Design and Manufacturing: CAD and manufacturing application	DYTW GUTÜD Model	4th grade
12	4	Robotic Coding	DYTW GUTÜD Model	4th grade
4	4	Mobile Application	DYTW GUTÜD Model	9th grade
5	4	Cyber Security	DYTW GUTÜD Model	9th grade
1	4	Introduction to Electronic Programming: Electronic programming and the internet of things	DYTW GUTÜD Model	4th grade

lesson planning model and GUTÜD (a pilot lesson plan model specifically developed for the DYTW program) were mainly utilized to examine the lesson plans. The 5E model is known to support inquiry in technology-rich environments (Çömez, Çavumirza & Yıldırım, 2022). The contents of the observation plans are listed in detail in the table below:

Two of the coders were experts in DYTW program content and practices. They could observe the best practices and instructors in the field. Hence, they decided to analyze the lesson plans for materials science. Before the analysis, three researchers studied the codes, categories and themes. In this pilot analysis phase, they read aloud the definitions of each category, precoding three of the eleven randomly selected lesson plans. The lesson plan codebook was prepared by the researchers and followed the 5E Lesson Plan (5E ILPv2) rubric developed for inquiry-based teaching (Goldston et al., 2013; see Güngören et al., 2020 for the Turkish version). Specifically, the evaluation rubric comprises seven sections, as shown in Table 3, covering the general characteristics of the lesson plan, the phases of the 5E instructional model, and additional lesson plan components, totaling 28 criteria. The section specific to the 5E instructional model includes 21 criteria. This rubric is a *Likert-type scale* with a score ranging from 0 to 4 points per item. The possible score ranges from highest to lowest were 0 and 112, respectively. *A Likert scale is "a rating tool designed to* *gauge survey participants' opinions, attitudes, motivations, and more. It provides a range of response options that span from one extreme attitude to the other, often including a neutral or moderate choice. This scale is used to capture participants' preferences or levels of agreement"* (Gay et al., 2012, p. 39) (Table 4).

Two researchers studied the initial coding process. Initial calculations for intercoder reliability, adjusted for chance agreement, were satisfactory (Cohen's Kappa, K = 0.70), and the discrepancies were resolved through discussion and partial recategorization of the opposition of quality of lesson plans reaching 100% agreement on the codes. During the analysis of the sample lesson plans ($n = 11$), two of the researchers reanalyzed all the plans individually and then checked their interrater agreement, which ranged from 0.50 to 0.97. The median number of agreements was 85.

The findings from the subscales revealed that the lesson plans were prepared in line with the 5E instructional model and comply with the features at a moderate level ($M = 3.43$). Nearly all the elements are presented in detail, and teachers can use the plan with minor modifications once they hold it. In terms of engaging learners, lesson plans tend to encompass almost all the features of learner engagement ($M = 3.13$). However, it did not provide sufficient opportunities for learners to discuss the main ideas related to weekly content and ask critical/higher-order questions. It was also recognized that formative and authentic assessments suggested in the lesson plans needed to be better structured and more understandable for trainers. In the phase of explanation and design, most of the expressions in the lesson plans could direct learners to explain basic facts and use skills related to the activity ($M = 2.88$). Trainers may not fully evaluate the understanding of the skills and misconceptions of some learners. In addition, deepening activities should provide opportunities for application to new areas and establish interdisciplinary connections better ($M = 2.85$). Additionally, safety issues were not addressed for learners' well-being during activities, engagements, and experiments.

Table 4 Lesson plan evaluation rubric

Likert scale sections	Sample items
1. Features of lesson plans	1.4.The list of tools/equipment/materials used in the lesson plan is presented completely.
2. Introduction: Engage	2.2.Entry (Observe) phase increases the student's interest/motivation in learning.
3. Explore	3.3. In the discovery phase, the learning activity is student-centered (Teacher questions may activate students' ideas or enable students to generate new questions. The student research-inquiry process requires students to question, use (manipulate) objects, use scientific process skills (if appropriate) *See the list of some science process skills.
4. Explain	4.1.There is a logical transition from the discovery phase to the explanation phase.
5. Elaborate	5.3. Elaborative activities enable students to interact with their newly learnt concepts or skills on a daily basis. Supports them to establish connections with daily life examples.
6. Evaluate	6.4.Evaluation criteria can be measured.
7. Additional lesson plan components	7.2.It is appropriate to evaluate the material selection results.

Discussion

Albert Einstein (1879–1955) once stated, “Education is not the learning of facts but the training of minds to think” (Whittaker, 1955). This view underscores the significance of both formal and nonformal learning environments in fostering critical thinking, problem-solving abilities, and scientific and technological skills. Framed by design thinking models (Rowe, 1987), social learning theory (Bandura, 1977), and the philosophy of technology (de Vries, 2005), this mixed-methods analysis of the DYTW program addressed three guiding research questions: (RQ1) What are the foundational techno-philosophies and visions of the DYTW leadership team? (RQ2) What techno-pedagogical elements are incorporated into the DYTW program by the program developers? and (RQ3) What comparative insights are evident in lesson plans on paper and lesson observations in practice?

In relation to RQ1, the leadership team, through interview responses, emphasized comprehensive analysis of learners’ needs and collaboration with experts and academics to improve the DYTW program. Interpreted through the philosophy of technology lens, this techno-philosophical stance reflects an intention to move beyond teaching isolated technical skills toward cultivating a broader understanding of what technology is and why it matters in society (de Vries, 2005; Dow, 2005; Mitcham, 1994). The emphasis on experiential and project-based learning approaches and on culminating project festivals can be seen as an attempt to make learners’ engagement with technology visible as both artifact creation and value-laden practice—echoing claims that artifacts and the ability to create and use them deepen understanding of technology itself (Dakers, 2006). At the same time, leadership acknowledged constraints, such as the hierarchical nature of the foundation and limited capacity for in-depth analysis of field data. From a philosophical standpoint, these limitations suggest that the techno-philosophical vision is only partially realized in practice: while the program aspires to support learners in developing their own philosophies of technology and engaging with the societal implications of technological change (Mitcham, 1994; Keirl, 2017), it currently lacks systematic feedback mechanisms that would allow for sustained critical reflection and refinement of that vision.

Addressing RQ2, the quality of lesson plans supported the leadership’s views that the content sequence and instructional strategies were organized in a way that actively engages learners. When read through a design thinking framework, these plans demonstrate an intention to structure learning around iterative, problem-centered, and hands-on activities, consistent with design thinking’s emphasis on experimentation, prototyping, and refinement in response to feedback (Rowe, 1987; Cross, 2006; Romiszowski, 2016). The planned use of projects, open-ended tasks, and interactive activities aligns with educational applications of design thinking that enhance learning and communication and foster interdisciplinary collaboration (Norqvist & Leffler, 2017; Hawkins et al., 2024; Leem & Lee, 2024). At the same time, the findings that lesson plans need more authentic assessment techniques, more open-ended questions, and more structured opportunities for higher-order thinking indicate that the design thinking orientation is not yet fully leveraged. From an interpretive standpoint, the lesson plans appear to foreground the process elements of design thinking (doing, making, tinkering) but provide less systematic support for reflection, iteration based on evidence, and evaluation of socio-ethical implications which are key components of design-oriented, techno-philosophical education (Morrison-Love, 2017; Nordlöf et al., 2021).

With respect to RQ3, comparing lesson plans with classroom observations showed that both formats generally valued the philosophy behind the foundation and DYTW's educational vision. The quality of content and implementation of instruction was efficient and interactive, consistent with evidence-based lesson plan rubrics. Viewed through social learning theory, these findings suggest that DYTW classrooms function as communities of practice in which learners observe trainers, collaborate with peers, and negotiate meanings around technological problems. These are conditions that support learning through modeling, vicarious experience, and guided participation (Bandura, 1977; Gross & Rutland, 2017; Benson et al., 2017). However, observations also highlighted the need for a more systematic approach to authentic assessment to evaluate learners' knowledge, skills, and attitudes in both written (on paper) and enacted curricula (in implementation). The absence of robust assessment tools limits the extent to which social learning processes can be made visible and fed back into instructional design. Interpreted theoretically, this contrast points to an "assessment gap" in the social learning environment: without systematic evidence of how learners are participating, collaborating, and internalizing techno-philosophical concepts, trainers' capacity to scaffold higher-order thinking and reflective practice remains constrained.

Taken together, these findings show that the DYTW program simultaneously engages the philosophical and instructional dimensions of technology education. The intersection of technology education and the philosophy of technology enhances teaching by addressing both technical skills and the societal implications of technology (Morrison-Love, 2017; Vries & Tamir, 1997). Philosophical frameworks guide curriculum development by encouraging program leaders and developers to incorporate technical knowledge alongside socio-ethical understanding (Nordlöf et al., 2021). Reconstructionism and pragmatism, for example, position learners as active agents who use technological knowledge to address social issues, thereby encouraging philosophical inquiry in curriculum design and promoting informed decision-making (Hill, 1997). Focusing on the social and cultural dimensions of technology shifts education from content-focused teaching to exploring the relationship between technology and society (Hansen, 1997). In DYTW, this philosophical orientation is evident in the emphasis on youth empowerment, social responsibility, and engagement with national and global challenges, resonating with approaches grounded in the "humanities philosophy of technology" (Mitcham, 1994).

The integration of digital technologies in DYTW can further be interpreted through post-phenomenology and constructionism, which highlight how technological artifacts mediate human experience and how learning emerges through making and manipulating digital tools (Wellner & Levin, 2023). The program's use of AI, robotics, and energy technologies provides fertile ground for such constructionist learning, where artifacts function both as learning tools and as objects of philosophical reflection. From this perspective, DYTW's emphasis on equitable access to high-tech learning opportunities supports educational equity by enabling underrepresented youth to participate in technologically mediated meaning-making processes (Ono, 2022). A balanced approach combining technical knowledge and philosophical perspectives thus creates a more comprehensive educational experience.

Previous studies, as well as the current research, emphasize that programs such as DYTW, which integrate maker activities, tinkering, and problem-based learning, offer learners valuable opportunities to engage in science, technology, and engineering practices (Norqvist &

Leffler, 2017; Pihlainen et al., 2021; Simpson et al., 2020). In design-thinking terms, these environments provide authentic contexts for ideation, prototyping, testing, and iteration. Unlike traditional classroom settings, nonformal environments allow students to engage in hands-on activities, critical problem-solving, and risk-taking in the development of engineering models. However, these opportunities come with challenges, as noted by Simpson et al. (2020), where failures are an inevitable and even necessary part of the learning process. Through a social learning lens, how trainers frame and respond to failure, as a shared opportunity for reflection and improvement or as an individual deficit, will shape learners' willingness to take risks and persist in complex design tasks.

The DYTW program's seven-year history demonstrates that innovative, technology-based approaches must be underpinned by strong philosophical foundations, which shape instructional design and determine effective teaching strategies (Molenda, 2003a, b). This finding directly relates to RQ1 and RQ2, showing how the leadership's techno-philosophical vision influences the instructional design decisions made by program developers. As de Vries (2005) argued, the philosophy of technology should inform teaching methods, ensuring that learners grasp both the technical and human dimensions of technology. The project-based and experiential learning approaches in this study appeared to enhance learners' understanding of technology's societal impacts, fostering a shift in their perspectives beyond formal education (Norqvist & Leffler, 2017). Trainers were encouraged to adopt inclusive teaching practices that address questions related to purpose, audience, and context, thereby integrating technology philosophy into the curriculum.

Furthermore, the importance of acquiring digital skills, particularly in high-tech fields such as AI, robotics, and energy technologies, is evident in the study's findings (Pihlainen et al., 2021). These skills, alongside the development of critical thinking and problem-solving abilities, were consistently enhanced through hands-on learning experiences that reflect both design thinking processes and social learning dynamics (Adiguzel et al., 2023). The role of technology education in creating equitable educational opportunities is highlighted by studies from Barkhuus and Lecusay (2011), Pihlainen et al. (2021), and Szpakowicz (2022), which argue that technology-based learning can help bridge educational gaps and reach disadvantaged students. DYTW's nationwide outreach thus not only embodies a design-thinking-oriented pedagogy but also operationalizes a techno-philosophical commitment to social justice.

The study also emphasizes the importance of integrating design thinking into nonformal education. Design thinking activates high-tech skills, psychomotor abilities, and higher-order thinking, which students may not develop in traditional educational settings (Küreci & Bulunuz, 2020). By expanding access to such learning environments across Turkey's 81 provinces, the DYTW program successfully reached underprivileged students, thus contributing to reducing educational inequalities (Kafai & Peppler, 2011). This approach also aligns with the broader goal of reducing the number of NEET (Not in Education, Employment, or Training) youth, as students are equipped with the skills necessary for future employment (OECD, 2022; van Laar et al., 2017). From the standpoint of social learning theory, these opportunities for sustained, collaborative engagement in authentic technological practices can support identity development as competent, future-oriented technology users and creators.

While the program's outcomes have been largely positive, particularly in fostering innovation and engagement, it is crucial to recognize that acquiring technology knowledge does not always translate into tangible results. As highlighted by Barkhuus and Lecusay (2011) and Szpakowicz (2022), learning about technology does not guarantee the development of skills or the achievement of specific outcomes. Interpreted through the three theoretical lenses, this gap underscores the need for (a) design-thinking-aligned assessment practices that capture iterative progress and creative problem-solving, (b) social-learning-informed supports that sustain practice and collaboration over time, and (c) philosophically oriented reflection activities that help learners connect their new competencies to broader life trajectories and societal challenges. For sustained impact, learners must continue to practice and refine their newly acquired technology-relevant skills beyond the immediate program context.

This research also highlights the importance of collaboration between public institutions and nonformal education authorities. As noted by Shantini and Sudiapermana (2016), lack of collaboration can lead to failures in ensuring equitable access to education. In contrast, the DYTW program benefited from strong partnerships with public ministries, science centers, and local authorities, which facilitated its reach and effectiveness, benefiting thousands of learners annually. These partnerships are not only organizationally significant but also philosophically aligned with a view of technology education as a public good that should be accessible across social strata.

In summary, RQ1 highlighted how the leadership's techno-philosophical foundations shape the DYTW's vision in line with a philosophy of technology that foregrounds human well-being, ethical reflection, and democratic participation. RQ2 identified how program designers implemented these visions through techno-pedagogical elements grounded in design thinking and experiential, project-based learning. RQ3 revealed both alignments and discrepancies between lesson plans and classroom practices, especially regarding authentic assessment and the realization of social learning opportunities. Together, these findings show that the DYTW program offers a valuable model for nonformal technology education, demonstrating the importance of a well-defined philosophical foundation, design-thinking-informed active learning methodologies, and socially grounded collaboration among stakeholders in providing equitable and impactful educational opportunities for youth.

Limitations

While the current study provided an in-depth analysis of the DYTW program through the perspectives of multiple stakeholders, including the leadership team, program designers, and various documents such as lesson plans and observations, several aspects warrant further investigation. Firstly, nonformal learning, by its very nature, lacks the structured framework characteristic of formal education, making it inherently flexible. This flexibility presents a limitation in evaluating a region-wide nonformal learning program, as regional differences in educational contexts—across developed, developing, and underdeveloped areas—could yield divergent results. Additionally, the moderate sample size, despite drawing from diverse data sources, could be seen as another limitation, as a larger sample size might enhance the generalizability of the findings. Alongside the sample size, the use of convenience sampling rather than random sampling further constrains the breadth of generalizability. As this study employed a mixed-methods approach with a significant qualitative component, it relied heavily on self-reports as primary data sources. Despite rigorous adherence to credibility, trustworthiness, and generalizability standards, self-reports inherently carry the potential for bias. Furthermore, both the leadership team and trainers may have unintentionally provided a more positive portrayal of the program's implementation. To mitigate this, anonymity was employed to safeguard the integrity of responses.

Further suggestions

Nonformal learning environments must establish a clear vision and philosophy to guide their objectives, ensuring alignment with learning outcomes, activities, and assessments, which collectively contribute to the quality of these institutions. Instructors should be better informed about the significance of teamwork and its impact on the overall goals of programs such as DYTW. To enhance this, in-service training and professional development seminars focused on group work techniques could be provided. Additionally, well-structured sessions on authentic in-class or on-site assessment, alternative evaluation methods, and measurement strategies would benefit instructors. Frequent and immediate feedback should be provided to stakeholders regarding their progress in both process and outcome assessments. Collaboration among nonformal science centers, public bodies, and NGOs should be strengthened to extend the program's reach while optimizing financial and human resources. Furthermore, material safety and precautions are crucial in nonformal learning settings, as these environments may not undergo the same level of inspection or quality certification as formal institutions. Finally, building on prior research and the current study, further mixed-methods research is needed to assess the quality and effectiveness of similar nonformal programs, thus informing future sci-tech education initiatives in nonformal settings.

Conclusion

This study examined the DYTW program as a community-driven, nonformal technology and science learning environment and addressed three interrelated research questions. In response to RQ1, the findings showed that visionary, techno-philosophically informed leadership is central to shaping a coherent educational vision that prioritizes equity, youth empowerment, and responsible engagement with technology. However, limitations in data use and feedback mechanisms indicate that this leadership needs to be supported by more systematic structures for ongoing reflection and evidence-based refinement.

Regarding RQ2, the analysis of lesson plans revealed that the program incorporates strong techno-pedagogical foundations, including project-based, experiential, and design-oriented learning activities. At the same time, the study identified clear needs for more robust and authentic assessment practices, more deliberate integration of higher-order thinking, and stronger alignment between intended outcomes and instructional strategies. These insights underscore that access to technology alone is insufficient; trainer competencies, pedagogical design, and assessment literacy are equally critical.

For RQ3, the comparison between lesson plans and classroom observations highlighted both continuity and gaps between planned and enacted curricula. While trainers generally upheld the program's philosophy and created interactive learning environments, inconsistencies in implementing assessment and fully leveraging social learning opportunities point to a need for more targeted professional development and clearer program guidelines.

Taken together, the study demonstrates that community-based nonformal initiatives like DYTW can play a significant role in mitigating educational disparities when visionary leadership, access to meaningful technological resources, and well-prepared trainers are brought into alignment. A key implication is the necessity of a more inclusive and comprehensive approach to digital and media literacy, one that goes beyond critical analysis to incorporate creative, technical, and ethical dimensions of technology use. By structuring these insights around the research questions, this study offers a conceptual and practical framework for strengthening nonformal technology and science education and provides a foundation for future research, policy development, and program design in this field.

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Data availability Data files could be shared upon reasonable request.

Declarations

Ethical approval Ethical approval was received from the official body and details were stated in the methodology part (IRB numbered: 2024/05 − 01). All authors approve that the study was conducted in the name of T3 Foundation to scientifically/objectively evaluate a branch of its educational operations. There are no financial interests. The study was specifically approved by the ethics committee (Number:2024/05-01, Date:17.05.2024) for research. Informed consent was also collected in parts where human participants were involved. All authors state that the research was conducted in accordance with the principles embodied in the Declaration of COPE and in accordance with local statutory requirements such as ethical approval of T3 Foundation. Authors declare that all participants (or their parent or legal guardian in the case of children under 16) gave written informed consent to participate in the study.

Informed consent Informed Consent to participate was received from all participants.

Consent to participate Consent to participate was received from all participants.

Consent to publish The authors state complete consent for the journal to publish the research study.

Statement Regarding Research Involving Human Participants and/or Animals Ethical approval included the necessary information regarding human participants.

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