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STEM Education as a Concept Borrowing Issue: Perspectives of School Administrators in Turkey

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Abstract

Purpose: As a borrowed concept, science, technology, engineering, and mathematics (STEM) education holds limited relevance in many country contexts. This study investigates how school administrators in Turkey view STEM education from three dimensions: (a) their understanding of STEM education, (b) their experiences of STEM implementations, and (c) their perception of their roles in STEM implementation.

Design/Approach/Methods: This phenomenological study analyzes the perceptions of school principals working in prominent high schools in Turkey.

Findings: The findings indicate that there are gaps in STEM implementation at both the conceptual level and the school level, including epistemological issues, infrastructural gaps, mismatch with overall organizational culture, and knowledge and skill gaps. Despite efforts to integrate STEM education into educational practices, significant deficiencies are making it an unrealistic practice in Turkey.

Originality/Value: While the literature on STEM education is expanding, a few empirical studies focus on school management in relation to STEM education. Arguably, despite promising to transform science and mathematics teaching, STEM education appears to have limited relevance to

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science and mathematics teaching in Turkey—rendering it yet another example of concept and policy borrowing in education.

Keywords

Educational policy, perceptions of school principals, policy borrowing, STEM education

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Introduction

When Russia launched Sputnik 1 into orbit in 1957, the United States initiated large-scale reforms in science, technology, engineering, and mathematics (STEM) education in an effort to generate scientific innovation, a key factor in maintaining their economic power and status in global relations (Bybee, 2013, p. 13; Fullan, 2009). The United States subsequently introduced several educational reform movements and initiatives in STEM, including "Nation at Risk" (Gardner, 1983), "Rise Against Gathering Storm" (Augustine, 2008), and "Educate to Innovate" (Office of the Press Secretary, 2009). Considered the starting point of STEM education, the "Educate to Innovate" movement sought to cultivate individuals with the necessary STEM qualifications (Office of the Press Secretary, 2009). According to Ng and Tsang (2021), transdisciplinary STEM education can be re-shaped with the help of constructionist learning. Investment in human capital is considered a critical factor in accomplishing economic growth and welfare (Acemoglu et al., 2005; Becker, 1964; Hanushek, 2011). As a result, the STEM movement served to improve the United States. education system and, in the long run, reinforce its economic competitiveness against rising nations in STEM fields, such as China and India (Ozturk, 2018).

After observing the STEM education movement in the United States, many countries initiated similar movements. However, attempts to integrate STEM education into different education frameworks typically failed to adequately assess the existing education systems and surrounding systems. As in the case of several other topics in education, the issue of borrowing (Phillips & Ochs, 2004; Steiner-Khamsi, 2014) or traveling policies (Nir et al., 2018) is evident in the STEM movements of many countries around the world. Essentially, the adaptation of STEM has tended to lack adequate assessment of how such policy corresponds to the local context. In general, the preconditions for borrowing policies center on dissatisfaction with the performance of the system, poor performance in external evaluation, failing to respond to economic development needs, political change, advocacy of researchers in the field, the interest of politics, the perceived superiority of other systems, and distortions of different groups regarding perceived deficiencies (Phillips & Ochs, 2004). Discussions on adapting STEM as a policy satisfy several of these preconditions. Scholars who have studied abroad have elucidated the poor performance of the system, arguing that it leads to poor student performance, negates current science and math teaching, and emphasizes the superiority of STEM education (Ozturk, 2018).

Scholars have explored several dimensions of STEM education, including definitional issues; access, and inclusion in STEM education; curriculum and instructional design; and the professional development of teachers in STEM education. However, the perception of administration at the national, local, and school levels has been ignored in discussions of STEM education. Although the literature has noted the role of school principals in reform movements, particularly with respect to technology-related changes, the perceptions and practices of school principals in STEM education have been overlooked (Anderson & Dexter, 2005; Flanagan & Jacobsen, 2003). Moreover, school administrators tend to have a very narrow understanding of STEM education (Brown et al., 2011). School principals play a critical role in framing the mission and goals of their school (Goldring & Pasternack, 1994). In view of Hoy and Miskel's (1987) emphasis on the role of school principals in instructional practices in schools, there is a need to uncover how school principals perceive and practice STEM education in schools. Indeed, despite the significance of principal leadership in curricular practices and school reforms, scholars have yet to explore the perceptions and experiences of school principals as the leaders of teaching and learning environments in STEM education. In addressing this gap, this study collects and examines the views of Turkish school principals regarding STEM education, thus providing insights on issues surrounding STEM education policy and its implementation from a management perspective. In addition to their perceptions of STEM education, this study explores how school principals locate themselves in the process of adapting and practicing STEM education. Accordingly, this study addresses the following three research questions:

1. How do the high school principals perceive STEM education movement?
2. What are the experiences of school principals in STEM practices?
3. How do school principals define their roles in the STEM movement?

Literature review

The concept of STEM education is highly controversial, with scholars raising a variety of concerns regarding this educational movement. Such debates have tended to focus on: (a) the conceptual and definitional ambiguity, (b) STEM as a topic of policy borrowing, (c) STEM and social justice, and (d) setbacks in implementation.

First, although several scholars have sought to define the philosophical basis—particularly in terms of its epistemology—and theoretical framework of STEM education, these aspects remain relatively overlooked in the literature. Consequently, the definition and conceptualization of

STEM education are relatively ambiguous. In this respect, the term "STEM education" is a "generic label" with a broad range of meanings (Ortiz-Revilla et al., 2020, p. 862). According to Vasquez (2015), practitioners and researchers differ in how they define STEM education, as well as in how they utilize disciplinary, multidisciplinary, interdisciplinary, and transdisciplinary lenses to understand the concept. Meanwhile, Chesky and Wolfmeyer (2015) emphasize the need to grasp the philosophies behind mathematics and science education to understand the philosophical background of STEM education and discuss how the traditional, transformational, and constructivist pedagogies take place in the implementation of STEM education. The concept has also been criticized in light of policy borrowing, social justice, and human resource issues in the application of STEM education in schools.

Second, as the movement is imported and does not consider the indigenous needs of the educational systems, STEM education raises the concern of policy or concept borrowing. Growing concerns over economic competitiveness have impacted education systems. For instance, international assessment programs like the Program for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS) have prompted countries to compete in education for economic reasons (Xie et al., 2015; Zhao, 2011). Atkinson (2012) argues that although STEM education is pursued as a policy for the same political and economic reasons, such policy is akin to pushing everyone to play the piano without an interest. Hoeg and Bencze (2017) have advanced similar criticisms, asking whether STEM is a "golden opportunity" or a "Trojan horse" insofar as policy has consistently ignored the issue of differential access to such education. As noted, borrowing policies, which work in some context but not necessarily in others, is a marked issue in STEM education. As a result, there is a lack of knowledge regarding how to integrate STEM education and STEM disciplines (Kloser et al., 2018). The spread of STEM education is evident in many countries; however, this spread has not resulted from a planned or organized policy (Hoeg & Bencze, 2017).

Third, various scholars have raised concern that STEM education will deepen education inequalities. Considering the fact that women are a disadvantaged group in STEM disciplines, Weeden et al. (2020) have highlighted the need to utilize local or school-based interventions to attract more young women to STEM fields for long-term solutions in STEM majors and workplaces. In this respect, organizations have launched a variety of initiatives intended to ensure the access of girls to engineering fields. For example, "Engineer Girls of Turkey" project receive support from the Ministry of National Education (MoNE), Ministry of Family, Labor and Social Services, and the United Nations Development Program (Türkiye'nin Mühendis Kızları, n.d.). In addition to gender-based disparity, regional disparities indicate that schools face differences in terms of infrastructure and human resources—another problem in STEM education overlooked in the literature. Xie et al. (2015) underscore the importance of school context in terms of district, teacher quality, science laboratories, and/or funding to establish and improve STEM practices. Moreover, prioritizing STEM implicitly tells society and parents that STEM fields are more important than non-STEM fields (Blustein et al., 2022), resulting in education and careers in non-STEM fields being ignored or disparaged. This imbalance is considered a social justice issue created by STEM education.

Fourth, there is a significant gap in human resources in relation to the practice of STEM in schools. In many country contexts, there are not enough teachers qualified to teach STEM fields. According to the results of a systematic review of teachers' perceptions of the integration of STEM education conducted by Margot and Kettler (2019), there is a marked need for professional development, including curricular practices and pedagogical strategies, as well as for collaboration among teachers to teach in an interdisciplinary manner. Meanwhile, following the promotion of STEM education by the Hong Kong Education Bureau, only 5.53% of teachers from different fields were sufficiently prepared to implement STEM education in Hong Kong (Geng et al., 2019). Such human resources gaps suggest that teachers are ill-equipped to implement STEM education (Colakoglu & Gokben, 2017), reiterating the need to train and develop teachers in an interdisciplinary way to ensure their preparedness.

Among other issues in the conceptualization and practice of STEM education, a few scholars have examined this topic at the leadership level. The transformation of traditional science, mathematics, and technological curricula teaching into an integrated STEM education curriculum requires a shift in teacher development, teaching practice, curriculum construction, and student positioning. However, such changes require the cognitive, affective, and behavioral readiness of school stakeholders (Oreg, 2003). Accordingly, such transformation is unlikely to occur without effective leadership, with school principals expected to orchestrate change processes (Starr, 2011). According to Park and Jeong (2013), teachers show less resistance to school reforms when the change is initiated by the school principal acting as an agent and facilitator of change. Moreover, research demonstrates that effective leadership support and strategic planning are important in the adoption of instructional technologies at the K-12 level (Elkordy & Iovinelli, 2021).

Method

This study was designed as a phenomenological study. Phenomenology is described as a methodology for capturing the experiences of a homogeneous group of participants' actions, thoughts, and assumptions regarding a phenomenon (Creswell, 2013; Patton, 2002), as well as the commonalties among participants in their experiences of the same phenomenon (Fraenkel et al., 2015). Phenomenological studies focus on understanding the social realities of an identified group of people based on their perceptions, lived experiences, and sensations (Gall et al., 2003). It, thus, presents an instrumental qualitative design for approaching any phenomena of interest from the perspective of a homogeneous group of people and reflecting on their experiences, ideas, judgments, and understandings (Moustakas, 1994). This study explores the commonalities among a group of Turkish principals in terms of their experiences, ideas, judgments, and understandings of STEM education. In doing so, this study seeks to (a) explore the experiences of school administrators with respect to implementing and managing STEM education in their schools, (b) understand their perceived roles in STEM education, and (c) capture the meaning they attribute to STEM education.

Participants

In Turkey, the varying quality of high schools has resulted in competition over the limited number of places available in quality high schools. Students are required to take a competitive national exam known as the High School Entrance Exam or LGS to determine high school placement. In Turkey, secondary education is provided via two types of high schools: general secondary education and vocational and technical secondary education. Various high schools provide general and vocational and technical secondary education (MoNE, 2020), with the most prominent comprising Anatolian High School, Science High School, Social Sciences High School, Anatolian Fine Arts High School, Multi Programme Anatolian High School, Anatolian Imam and Preacher High School, and Anatolian Vocational and Technical High School. Each of these schools implements a unique curriculum aligned with their specific purpose. In the province of Ankara, a total of 82 high schools of different types accept students based on their LGS exam results (MoNE, 2018). The MoNE categorizes schools with a greater application of STEM-related practices as "project schools."

This study's participants comprise high school administrators working in the province of Ankara in Turkey. This study employed the criterion sampling method to identify potential participants (Patton, 2002). For this study, 11 school administrators working in project schools were selected and interviewed. Participants were selected from three different high schools, namely Anatolian High School ($n = 7$), Science High School ($n = 2$), and Anatolian Imam and Preacher High School ($n = 2$). All participants were male. The gender composition of the participants in this study is reflective of the population, with the majority of school administrators in Turkey being male. More specifically, this study interviewed eight school principals, two vice school principals, and one deputy school principal. The participants majored in a variety of fields, including Turkish literature, French, Culture of Religion and Ethics, Chemistry, Mathematics, and History. Only two participants had engaged in graduate study; one held a Master's degree in Educational Administration, while the other was pursuing a doctoral degree in the same field.

Data collection procedures and data analysis

As noted, this study interviewed 11 school administrators from three project schools in Ankara, Turkey. Interview questions were structured based on the NYC Department of Education (NYCDOE) STEM education framework (NYCDOE, 2016), and covered the following domains: (a) school vision and structure for success; (b) STEM curriculum instruction and assessment; (c) strategic partnership; and (d) STEM college and career readiness, which includes planning and preparations for K-12 level. Examples of interview questions include: "Is there any consistency between the school vision and STEM education? If there is, how so?"; "Are there any examples of implementation of STEM education in your school? If so, how do you integrate STEM education into your educational practices?"; and "What are the attitudes of teachers and students toward STEM education in your school?" Participants were also asked to define STEM education; define their role in the school with respect to educational processes; describe how they go about realizing the school's mission, vision, and goals; describe the educational environment of their school; and identify how their school differs from others in terms of educational and administrative practices. The average duration of the interviews was 43 min.

In addition to interviews, data were collected from the websites of the participants' high schools. Collected data include strategic plans, mission and vision statements, school properties, and announcements of school events and activities published on school websites. Document analysis was thus used to support the data obtained from interviews regarding participants' experiences of STEM education in their respective schools. Prior to data collection, ethical consent was obtained from the Human Subjects Ethics Committee and legal permission from the MoNE.

All data were transcribed verbatim and analyzed using MAXQDA 2018.2 (VERBI Software, 2018). The results of data analysis are presented under themes based on this study's three research questions.

Findings

Interview and document analysis suggest that there are important gaps in the STEM readiness of Turkish project schools, both at the conceptual level on the part of the school administrators and at the organizational (school) level in terms of hardware or infrastructure. More specifically, the document analysis of the mission and vision statements, strategic plans, and physical infrastructure of the selected schools indicates that STEM education is not recognized in the schools. Indeed, STEM education does not feature in the mission, vision, and strategic orientation of the selected schools. Turkey possesses a highly centralized education system, granting individual schools little autonomy in identifying their strategic orientation and generating of resources to realize these orientations. Therefore, the lack of recognition of STEM education in the strategic plans or mission and vision statements of these schools may reflect the strategic orientation at the national level. A lack of recognition of STEM education was similarly evident in the interviews. As one interviewee stated, “In my opinion, there is no knowledge and equipment to integrate STEM into our mission and vision statements” (P1). Consequently, there is a marked gap between theory and practice in Turkey’s STEM education, with the STEM movement appearing to be a never-realized discursive inclination in the Turkish education system.

Moreover, the schools lack the hardware or physical infrastructure for STEM education. Although technology is one of the bases of STEM education, some schools lack the basic technological infrastructure necessary for such education, including Internet infrastructure, tablets for each student and teacher, and projectors or smart boards for each classroom. Such resources are expected to be provided by the Movement for Enhancing Opportunities and Improving Technology (FATIH) project, which was initiated by the MoNE in an effort to enhance educational practices in all schools by focusing on the five key dimensions of accessibility, productivity, measurability, equality, and quality. Accordingly, the project seeks to equip every school with broadband Internet access, Internet infrastructure, and high-speed Internet access; every classroom with an interactive board and wireless Internet access; and every teacher and student with rich content in related disciplines via tablets and the Educational Informatics Network (EBA). The goal is to help students develop the skills necessary for life in the twenty-first century, including problem-solving, creative thinking, collaboration, and technology use through technological opportunities (Innovation and Educational Technologies General Directorate [YEGITEK], n.d.).

In this respect, interviewees noted limited laboratory facilities as one of the clearest examples of the limited infrastructure for STEM education. According to one participant, “The best example I could give about this (STEM application) is the biology and chemistry lab. We have one lab for these two subjects” (P9). Another school administrator noted the same issue, “I speak openly that I have no place in the school that could be accepted as a STEM room or anything close to it” (P5). Of the 11 participants, only one indicated the presence of initiatives toward building a STEM infrastructure, namely the establishment of a “STEM Garage” inspired by the background of Steve Jobs and Steve Wozniack (P10).

The perceptions of school principals regarding STEM education

Content analysis revealed three key themes reflecting the perceptions of school administrators regarding STEM education: namely a “dashed” definition of the concept rather than a full conceptual understanding, lack of policy, and little confidence in the value of STEM education for the Turkish context. In light of the various definitions of STEM presented in the literature and the lack of a concrete philosophical and epistemological base, it is hardly surprising that school principals evidence little understanding of STEM education. This confusion is compounded by the lack of a concrete STEM education policy. Indeed, although STEM education created a stir in Turkey, particularly in schools and universities, through academics returning from the United States, the MoNE has yet to establish firm policies in this regard. As a result of this "dashed" definition and the lack of STEM education policy, school principals exhibit wariness regarding the appropriateness and potential contribution of STEM education for the Turkish context. These issues are worth exploring further.

"Dashed" definition of STEM education. The school administrators interviewed in this study did not relate STEM education to their school practices. As one interviewee noted, "STEM is not an area I have a grasp of, although I have thought and read about it a lot. I think that STEM education is not defined completely and clearly in Turkey. It seems that it is narrowed to the context of robotics" (P1). The tendency to view STEM education in relation to mechatronics and robotics was similarly noted by another interviewee, "There is a tendency for education in the areas of mechatronics and robotics, which are considered good for brain development" (P4). In this respect, another participant critiqued the approach to STEM education as follows:

> I think STEM could be applied to all areas. If it is a technology, then this technology should not be restricted only to physics, chemistry, biology or mathematics. The mistake is that we limit our definition to these fields. We need to cover other fields as well. If you limit STEM education to these fields, you cannot apply it; you can only have a theoretical course just like physics, chemistry, biology. Then it does not serve to its goal. (P10)

Interviewees also revealed that STEM education was difficult, particularly, insofar as there is a lack of knowledge about STEM education. As one administrator noted,

> I do not have much knowledge about STEM education but it could be related to science, mathematics, and even physical education. […] Science, mathematics, and engineering fields are not far away from one another. In fact, they are interwoven […] and if this educational practice means visualizing, adapting, and accommodating the knowledge, then it could make sense. (P5)

Such definitional issues suggest that the concept and epistemology of STEM education have not been embraced in practice. Interviewees linked STEM education to fields, such as robotics, mechatronics, software development, and artificial intelligence, or to engineering in general, but not to current curricular practices at the high school level. The issue of a "dashed" definition of STEM education is reflected in such perceptions. Indeed, one interviewee asserted, "We do not have any implementation of STEM education as well as software development" (P3). Another school principal approached STEM education as a career goal for students seeking to enter engineering programs at university, noting, “With the outstanding support of our teachers in chemistry, physics, and mathematics, even before the STEM education trend appeared, our students had already been interested in selecting natural sciences or engineering programs in undergraduate level studies in universities as being tied to STEM education” (P6). Although the literature presents the concept of STEM education as an interdisciplinary one, this interdisciplinarity is not evident in practice. Certainly, participants’ understanding of STEM education as no more than its acronym reflects their ignorance of its intended interdisciplinarity.

The debate over STEM versus STEAM pertains to the philosophical basis of the concept. Although the concept was originally conceived as STEM, scholars later suggested that it should be amended to include the arts and humanities (“A”), that is, STEAM education. However, the recurring debate surrounding STEM education suggests that it is treated as a portmanteau concept, where additional terms and concepts are assimilated into the original concept. This controversy is reflected in the comments of this study’s participants. Indeed, where one argued that “I do not think that different fields can be added to STEM education. It cannot happen in practice. How can you add humanities into science? It cannot be added” (P3), another concluded that “Having a package including STEM fields all together with the arts and humanities is the right thing to do” (P7).

Document analysis revealed that all schools prioritize arts and humanities subjects. However, there is confusion surrounding the integration of these subjects into the interdisciplinary educational practice of STEM education. As one school administrator reported, “There could be an absolute connection with geography and STEM areas; with history, there could be a connection at some point. Literature, literate thinking, and splitting your thoughts into the pen, I don’t know. That is a question mark” (P5). The majority of interviewees lacked an understanding of both the STEM and STEAM education concepts. Although this confusion is indicative of the ambiguity of the epistemological and philosophical bases of the concept of STEM education, the discussion surrounding STEM versus STEAM education centers on the prioritization of the arts and humanities without integrating with science, mathematics, technology, and engineering disciplines.

The contributions (!) of STEM education in the Turkish context. The second theme revealed by school administrators’ perceptions of STEM education centers is their lack of confidence in the value and potential contributions of STEM education in the Turkish context. Indeed, participants exhibited little confidence in the ability of STEM education to respond to all of Turkey’s education needs and requirements. As one interviewee explained, “You consider education as a whole. When you want expertise in social or scientific areas, you can obtain it through university level education. Organizing the schools and the curricular activities solely around STEM education is not a valid approach” (P6).

STEM education also raised questions regarding the risk of sacrificing other teaching fields, with one interviewee asserting, “Life or the school is not just about science and technology. (The) ‘I will teach just STEM and leave the rest’ approach is inappropriate” (P7). For the school administrators interviewed for this study, emphasizing STEM education meant ignoring the importance of disciplines related to the social sciences, arts, and humanities—a situation they deemed untenable. Indeed, one school principal emphasized the importance of equipping future generations with knowledge and skills that cannot be replicated or performed by robots (P1).

In relation to this theme, school administrators noted that not every educational policy can fit into all contexts. As one of the interviewees stated, “We should not come close to everything that is implemented by others or (that we have heard of) (…) everything does not fit everyone” (P8). Another interviewee (P3) illustrated this issue by recalling the efforts to integrate Total Quality Management (TQM) in Turkish education contexts when the approach was popular globally. According to P3, the scholars investigating the adoption of TQM in the Turkish education context eventually gave up, concluding that it could not be applied in this context. Broadly speaking, interviewees felt that relying on a single educational approach was unreasonable, regardless of its global popularity. As such, the wariness of school administrators toward STEM education and its potential contributions is hardly surprising, particularly when considering its “dashed” definition and the lack of policy.

Policy gaps in the implementation of STEM education. The third theme to emerge from the interviews pertains to this study’s first research question, namely the existence of marked policy gaps in STEM education. Interviewees noted the need for policies to facilitate the implementation of STEM education in the Turkish education system, including policies to position STEM education in public schools, define the legal basis of STEM education, provide a set of interventions addressing the drawbacks of STEM education, and ensure the supply of materials needed for STEM education. Most agreed that there is a disconnect between educational reforms and implementation. Based on their experiences of top-down reforms, the interviewees voiced concern that STEM education was beset by the same problem due to a lack of readiness and policy borrowing issues. As one interviewee asserted, “Unfortunately, the MoNE has approached STEM education, as in other cases, without assessing the applicability of the topic in practice” (P8).

Interviewees further noted the emergence of social justice issues as a result of implementing STEM education without a clear and well-designed policy. According to one perspective, STEM education deepens the inequalities in education as the opportunity for such education is not available to the majority of students. This concern was similarly raised by an interviewee:

> When it comes to the establishment of computer centers and robotics workshops, we could not go further. Our biggest drawback is that there are few public schools who can do it apart from the private schools. Those who can do get help from companies to set up this STEM environment. STEM education comes with a huge financial burden. (P1)

With respect to social justice concerns, interviewees identified the high-stakes university entrance examination as an issue. Based on theoretical aspects of key disciplines, this exam was seen as impeding the practical implementation of STEM education insofar as it hinders the implementation of different education approaches due to the need to prepare for this examination. Interviewees also felt that STEM education requires a different curriculum, which is another drawback in its implementation:

> You are faced with a dilemma here. There is a university entrance exam and the parents want their children to be prepared for this exam. […] They want their children to study in the evening at home. […] getting good results in the exam in order to qualify for the specific university and program creates a dilemma for us […] [because] what the parents want and what teachers teach differ from each other. (P10)

One aspect of this policy gap in the implementation of STEM education is the lack of training and development opportunities for teachers and principals. The lack of knowledge regarding what STEM education is and how to implement it necessitates professional development for interdisciplinary teaching facilitated by experts knowledgeable about interdisciplinary teaching-learning practices or projects related to STEM areas. One interviewee noted the challenge of sustaining expert support for STEM education in his school. School administrators typically perceived time spent on STEM education practices as additional to or outside curricular activities, generally likening such practices to science projects.

Finally, a lack of facilities for STEM education presents another challenge to its effective implementation. Apart from schools with dormitories, there is not much opportunity for students to study in laboratories 24 hours a day. As one interviewee asserted,

> There is a need to create time for students. They need to have time to try things in labs and "garage," they need free time to attempt [things]. Steve Jobs did not work in the daytime, but studied at night in his garage. They make use of their free time. […] If this school was a boarding school, I could activate the labs, and I could apply the best education with the support of two or three of our teachers. […] When students meet their basic needs after the classes end [3:30 pm], they will enter the laboratories voluntarily. When they do this voluntarily, they do excellent work. (P10)

In this respect, interviewees advanced the need for full-time access to schools to enhance commitment in STEM education. School administrators also advocated the need for more resources so as to better implement STEM education. According to one interviewee,

> We do not have enough resources. We get financial support from non-governmental organizations. There is 90 percent lack of funding but we do not make this an excuse. […] When our computers are not good enough, we take our students to a place where there are expensive computers if this helps them study. This is a sacrifice. (P8)

School principals' experiences of STEM education

The participants interviewed for this study documented their experiences with STEM education, centering their school background in terms of student and teacher quality and current science-based activities. As part of the criterion sampling, this study selected project schools who admitted students based on their LGS results. In this respect, these schools seek to be the best given that their students are qualified in terms of academic achievement. Certainly, all of the interviewees identified student quality as an influential factor in the educational environment, one allowing for the implementation of new approaches. According to one school administrator, the successful implementation of STEM education depends on the student qualifications, potential, knowledge, and enthusiasm (P9). Another interviewee maintained:

> Actually, the students are ready for STEM education. Especially the students we are working with in our school, [who have] already learned about computers and programming. This generation is motivated toward STEM fields and familiar with STEM education. The activities related to STEM education in our school, such as programming and robotics classes supported by computers, are especially attractive to students. (P1)

Although student readiness is important, it is not the only indicator of STEM education implementation. Indeed, several interviewees emphasized the importance of teacher motivation to try new education practices in the implementation of STEM education. For instance, motivated teachers and academically committed students are more likely to participate in scientific projects and competitions. However, in most schools, teacher enthusiasm is considered a teacher characteristic, inferring that not all teachers are willing to try new things. One of the interviewees illustrated this issue as follows:

> Since we cannot change the teachers, we limit the [STEM] topics to classes only. For example, [under the constructivist curriculum, which was implemented in the Turkish education system in 2005], teachers need to construct knowledge, [but] most of them cannot do this. Since 2005, there have been only a few teachers who do this. Even this approach has not been [fully] implemented.

> Implementing STEM education requires broadening the context of practice and going beyond the classroom. Additionally, we do not have team spirit, teachers try to handle STEM education in an individualistic way […] It is difficult to accomplish anything with this mindset. (P10)

Another participant pointed to the role of teamwork in proving more effective STEM education practices. In the selected school, teamwork facilitates the learning of teachers from one another regarding STEM practices. As the school administrator explained, "The teachers share knowledge and experiences with one another. They ask for and get help from one another about STEM implementation" (P8).

The selected schools frequently participate in competitions related to STEM education, which are organized by TÜBİTAK, the leading funding agency for scientific research in Turkey. The schools typically prepare projects that are independent to teachers' formal job titles, with these activities entirely dependent on the voluntary participation of both teachers and students. Teachers and schools typically collaborate with scientific research organizations, including universities and research agencies. Such voluntary STEM education activities include robot competitions (P8), artificial intelligence competitions (P1), and arranging activities during programming week (P6). These practices demonstrate that the motivation of teachers is crucial to progress in STEM education.

The perceived role of school principals in STEM education

During the interviews, participating school administrators were asked to define their role in STEM practices. Their answers revealed that they saw themselves as facilitators, supporters, or motivators rather than prime implementers of STEM education.

School principals as facilitators. The majority of school administrators described themselves as facilitators who respond to the needs of teachers and students and remove the challenges or obstacles impeding the implementation of STEM education. In this respect, interviewees identified supplying the material needed for STEM applications as a key aspect of their role as facilitators. In addition to finding and supplying the necessary materials, facilitators considered helping teachers develop professionally and learn new teaching methods as an important part of their role. In other words, they undertook instructional leadership roles and supported teachers' professional development. Such participants described their roles as follows: "(My role) is making life easy for teachers when they are doing their job" (P10); "I could describe myself as both leader and servant. I try to meet the needs of the students and teachers" (P8); and "For example, we invite the experts to brief and train the teachers in STEM education" (P1).

School principals as supporters. Interviewees also defined their roles as providing support in both communication and work processes. One school administrator explained that he practices an open-door strategy, “When students have some problem or ideas (including issues about STEM), they come and talk about it. I support them in the problem subject and try to find a solution” (P9). Another concentrated on coordinating teachers to ensure more effective STEM practices: “Mathematics teachers should not be disconnected; similarly, physics teachers should not be disconnected. We need to bring them together from time to time” (P5). Essentially, such administrators sought to create a positive climate that serves STEM education. As one of the principals stated, “My job is to make teachers pleased and peaceful, and make plans” (P3).

School principals as motivators. Finally, some of the interviewees saw themselves playing a strong motivator role in their schools. For instance, one principal noted, “We provide them (teachers) with an appropriate (teaching) environment and try to motivate them” (P6). Another explained, “I have the role of creating opportunities and guiding and controlling them at the same time. I have a leadership style to support teachers to improve themselves” (P11). The principals perceived their motivator role as vital for STEM education as well as other practices in schools.

Discussion and conclusions

This study investigated the perceptions, practices, and roles of school principals in STEM education in three different types of Turkish project schools. Despite attempts to integrate STEM education practices into school frameworks (YEGITEK, 2016), deficiencies make STEM education an unrealistic practice in Turkey. The main obstacles to the implementation of STEM education include epistemological issues, ineffective policy (i.e., policy gaps and disconnect between policy and the overall organizational culture), financial concerns, and knowledge and skill gaps.

Epistemological issues and definitional ambiguity hinder the implementation of STEM education in Turkey. In accordance with the findings of this study, Brown et al. (2011) argued that STEM education is poorly understood by school administrators. While YEGITEK (2016) defined STEM education as an interdisciplinary educational practice providing holistic approaches to problem-solving, this study’s participants asserted that the approach is about applying knowledge rather than teaching abstract knowledge in STEM fields. This approach to STEM education contradicts actual STEM applications. Although different interest groups (e.g., politicians, academics, educators, and non- and for-profit organizations) have shown interest in STEM, there remains no clear definition of the concept (Daugherty, 2013). Essentially, the popularity of the concept of STEM education does not go hand-in-hand with its application. Firm epistemological foundation of curricular practices and training of teachers and school administrators is not evident in the Turkish context.

The findings of this study show that STEM education is not a home-grown movement but a borrowed practice. Indeed, academics trained abroad—including in the United States—have been the proponents of the STEM education in Turkey. However, these proponents are far removed from the local realities of Turkish schools, impeding the effective implementation of STEM education. Broadly speaking, STEM appears to be a policy issue in Turkey and suffers from the typical drawbacks of borrowed educational policies. According to Nir et al. (2018), in policy borrowing, there is a gap between the policy itself and the local context of the educational system. This is the case in Turkey, where the realities of the Turkish education system and STEM education clearly contradict each other. For example, in Turkey, a high-stakes and extremely competitive exam regulates the transition from secondary to tertiary education. In this context, priority is given to training students for this high-stakes exam rather than STEM education. In addition to the borrowed policy issue, there is a need to train teachers in interdisciplinary teaching methods, reform elementary and secondary education curricula, standardize testing, and regulate the number of science and mathematics courses (YEGITEK, 2016).

Although there is a growing trend of curriculum convergence toward STEM subjects (Zhao, 2011), contextual differences should be considered in responding to local, regional, and national level needs. In this respect, as the participants of this study emphasized, STEM education does not respond to the needs of Turkey. STEM education reflects the priority of the United States to cultivate their workforces to contribute to the national economy through innovation in STEM areas (Gonzalez & Kuenzi, 2014). In contrast, Turkey is not concerned about a lack of careers in STEM areas, but the brain drain of qualified graduates who have developed their skills in STEM fields. According to the data collected by the Higher Education Council of Turkey (HEC), in the last four years, 176,989 individuals have graduated from engineering-related programs, while 27,959 have graduated from the natural and applied sciences (HEC, 2017, 2018, 2019, 2020). Additionally, according to official data shared by Turkish Statistical Institute (TUIK, 2020), unemployment figures for 2019 include 133,000 engineers, 39,000 scientists, and 10,000 mathematicians. As such, there is a disconnect between the returns of STEM education and the educational policies Turkey needs.

One of the core concerns regarding STEM education is related to its perceived impact on social justice. Although the school administrators interviewed for this study did not report an effective implementation of STEM education, they did note concern over the channeling of education outcomes to the limited number of STEM education receivers. In this respect, although the FATIH project was intended to equip all schools with smart boards, tablets, computers, and Internet infrastructure, there are still schools without this foundational technological infrastructure. Therefore, the differences between schools in terms of infrastructure—including technological hardware and other resources—underscore the need for equitable education opportunities across schools. Scholars have raised similar concerns regarding STEM education and social justice (e.g., Gouda et al., 2013; Lu et al., 2015).

Study participants also raised concerns about the readiness of schools to practice STEM education. A meta-analysis of the effects of school administrators' behavior indicates that student outcomes are related to the leadership skills of school principals in terms of their instructional and organizational management (Liebowitz & Porter, 2019). However, the school administrators interviewed in this study admitted to lacking knowledge about STEM education. Implementing STEM education is not hassle-free for school administrators or teachers. Certainly, both the participants in this study and the existing literature indicate the need for the professional development of teachers with respect to STEM education (Bartholomew, 2017; Chai, 2019; Havice et al., 2018). In this study, school administrators highlighted teachers' insistence on continuing the traditional way of teaching despite educational reforms encouraging change in this regard.

Finally, participant interviews indicated a readiness gap at both the individual and organizational levels. Readiness starts with the school principal leading change in the school environment and supporting and initiating the implementation of STEM education. However, school administrators appear to lack the necessary knowledge of how to go about achieving this goal. Therefore, there is a need to create an organizational culture nurturing STEM education (Kondakci & Kulakoglu, 2018), which necessitates investment in both the physical infrastructure of schools and the professional development of its human resources. As the participants of this study indicated, there is a top-down implementation in the mission and vision statements as well as strategic planning of Turkish schools. However, resistance to change and the use of micro-political strategies to prevent change processes have been observed among teachers in response to external educational policy interventions. In this respect, the school principal is regarded as the "purveyor" of such policy (Starr, 2011). Accordingly, rather than relying on old-fashioned change processes, it is necessary to identify a new perspective of change—one based on social constructivism and moving in a bottom-up direction. This also reflects the need for school principals to practice distributional leadership rather than removing themselves from the process (Beycioglu & Kondakci, 2021).

This study is one of the first to examine the perceptions and roles of school administrators in STEM education. However, the study has several limitations. First, study participants were selected from science and project high schools in Turkey's Ankara province. It is likely that the experiences of principals in different schools and regions will differ significantly. Second, this study sought to investigate the perceptions of high school administrators, who represent the management side of schools. Therefore, future studies should include a more diverse sample, including teachers, school principals, policymakers as well as different types of high schools. Moreover, quantitative studies may prove fruitful in revealing and generalizing the outcomes of research on the experiences, perceptions, and roles of school administrators in STEM education.

Contributorship

This article is based on the master's thesis "The Unknown Territory of STEM: The Perceptions of High School Administrators," written by the first author under the supervision of the second author. Both authors worked jointly to shape each section of this empirical article.

Busra Kulakoglu conducted interviews with the school administrators and document analysis. She was also responsible for writing the main body in the literature review, method, and findings sections, as well as data analysis, process of article revision, and responding to reviewers' comments. The thought of studying this topic was originated by Yasar Kondakci. He wrote the main body in introduction, and discussion and conclusions sections, and contributed to the data analysis, process of article revision, and responding to reviewers' comments. Two authors worked collaboratively in each section to finalize it.

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