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Effects of STEM Education on Unemployment Types: An Applied Science Case Study

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Rapid technological transformation and digitalization have reshaped labor markets by changing skill demands and affecting various types of unemployment. In this context, STEM (Science, Technology, Engineering, and Mathematics) education has gained prominence as a means of equipping individuals with 21st-century skills and improving employability. This study investigates teachers' perceptions of STEM education's impact on different unemployment types. A total of 45 teachers were selected through criterion sampling, and data were collected using a semi-structured interview form and analyzed with inductive content analysis within a structured qualitative design. Findings indicate that teachers view STEM education as reducing multiple unemployment types, especially involuntary, frictional, cyclical, structural, hidden, technological, and seasonal unemployment, by enhancing qualified human capital, fostering interdisciplinary skills, promoting entrepreneurship and innovation, and supporting adaptability and lifelong learning. However, participants noted its limited effect on natural and real wage unemployment. Expectations of higher wage demands and labor substitution by technology suggest STEM education may not significantly reduce voluntary or real wage unemployment and could even increase technological unemployment. Overall, STEM education is regarded as a strategic tool for improving employment outcomes, although its effectiveness depends on economic conditions and public policies, highlighting the need for future research using mixed methods and multiple stakeholders to better understand its relationship with labor market dynamics.

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Introduction

In recent years, many countries have issued calls for STEM education. The purpose of these calls is to provide individuals with the knowledge and skills necessary for the economy through STEM education. In addition, countries believe that STEM education will positively effect the emergence of new professions, the disappearance of existing professions, the labor force, and types of unemployment (Akcan et al., 2023). Therefore, integrating STEM education into the educational process from an early age will increase the number of individuals who will choose STEM fields in the future (Yıldırım et al., 2022). Otherwise, the desired outcomes may not be achieved. For example, Allen (2016) emphasized in his study that half of the students' interest in STEM fields decreases until they reach the 8th grade, and they do not choose careers related to these fields. The fact that STEM education contributes to a skilled workforce also increases the expectations of STEM education. The increase in expectations of STEM education has become the focus of studies investigating the effect of STEM education on the workforce. In this direction, many studies have investigated the relationship between STEM education and the labor market (Salzman & Lieff Benderly, 2019; Bacovic et al., 2022). For example, Kanpton (2019) emphasized that STEM education is effective in training engineers who will work in the manufacturing industry. These studies focus on the contribution of STEM education to gender equality in the labor market and the positions and sectors in which individuals with STEM education are likely to work (Osei-Kofi & Torres, 2015; Yıldırım et al., 2022).

It shows that STEM education has positive and negative reflections on the labor force and unemployment types. For example, technological unemployment occurs as a result of the transformation of products resulting from STEM education into innovation (Swanepol, 2023). In addition, STEM education is an important factor in the emergence of new business areas and new occupational groups (Çepni & Ormancı, 2018). It is understood that STEM education has a positive effect on the ease of finding a job when they first get a job (Sassler et al., 2017). This shows that STEM education reduces fractional unemployment. Reducing gender inequalities in the labor market may conclude that all types of unemployment can be reduced more easily. For example, Sheltzer and Smith (2014) emphasize that women are in a disadvantaged group compared to men and that STEM education will have a significant effect on minimizing this disadvantage. Similarly, Xu (2015) examined the effect of STEM education on gender-related unemployment. Because of the analysis, it was concluded that STEM education will reduce gender-related unemployment problems. In addition, Akcan et al. (2023) emphasized that STEM education has positive effects on the labor force and reduces unemployment. King Miller (2017) emphasized the importance of STEM education in ensuring gender equality. In this study, the researcher emphasized the challenges faced by women in business life and the role of STEM education in solving these challenges. It is emphasized that in the African region where unemployment is high and women who are in the disadvantaged group in these regions, permanent employment will be possible with STEM education. Therefore, STEM education for women will play an important role in reducing gender inequalities.

In some cases, the number of women in STEM education has increased, but the number of women in the workforce has not increased to the same extent (Walker, 2018). Another situation that can be seen as one of the results of this research is that there are also studies in the literature that conclude that STEM education does not affect gender inequality in the labor market or increases gender inequality. On the other hand, studies that support this situation have concluded that STEM education increases gender inequalities in the labor market, depending on the situation and conditions. Some of these studies: According to Piva and

Rovelli (2022), STEM education increases the gender gap in entrepreneurship and relatively blunts entrepreneurship. VanHeuvelen and Quadlin (2021) examined the gender gap in STEM employment in America. They concluded that women with STEM education are more disadvantaged in labor market entry and post-employment wage policies.

In this context, STEM education has many direct and indirect effects on the labor market (Çepni & Ormancı, 2018). It is possible to better study these effects and gain more benefits from STEM education. In fact, the effects of STEM education on the types of unemployment have not been investigated. However, the results of some studies emphasize that STEM education can be effective on unemployment types and should be studied (Akcan et al., 2023; Sassler et al., 2017; Knapton, 2019). Therefore, the opinions of STEM-educated teachers on STEM education and unemployment types are extremely important. In fact, there are not enough studies in which the opinions of teachers on STEM education and unemployment types are examined in detail (Yıldırım et al., 2022). This situation makes this study important. Therefore, the views of teachers on the reflection of STEM education on STEM education and unemployment types were considered. In this direction, the problem of the study was determined as "What are teachers' views on the reflections of STEM education on unemployment types?".

STEM education's functioning at the individual (micro) level and its relationship with types of unemployment—typically addressed within a macroeconomic context—need to be theoretically clarified. Although types such as structural, frictional, technological, and natural unemployment arise due to macro-level economic dynamics, they are also determined by the combined effects of individuals' acquired skills, the quality of labor supply, and the matching processes that occur in the labor market.

Macroeconomic growth is the most important of macroeconomic aggregates and macroeconomic performance targets. There are studies suggesting that STEM education affects economic growth and even contributes to sustainable economic growth (Billing et al., 2023; Gülen et al., 2025; Jumagaliyeva, 2024; Mouton & Rewitzky, 2025; Rizki et al., 2024).

STEM education offers a multidimensional educational opportunity by integrating science, mathematics, engineering, and technology. One of the most important contributions of this multidimensional and contemporary form of education is that individuals who receive STEM education develop their skills in many respects. There is also a large body of recent literature on this topic (Bai & Tian, 2025; Dogaru et al., 2025; Lin et al., 2025; Özbek, 2025; Özpir & Yildirim, 2025; Panqueban et al., 2025; Xi & McLean, 2025; Yang et al., 2025).

The literature contains a large number of recent studies demonstrating that skill development directly affects employment, wage formation, and labor market outcomes (Alam et al., 2024; Amrahi Tabieh et al., 2025; Chemli et al., 2024; Choudhury et al., 2025; Kana & Letaba, 2024; Tolmie, 2025; Valverde-Rebaza et al., 2025; Wu et al., 2025). Similarly, both the probability of becoming unemployed and the duration of unemployment are influenced by individuals' skill levels (Bansal & Mathur, 2024; Cohen et al., 2025; Flórez & Gómez, 2024; Hänni & Kriesi, 2025; Misra et al., 2025; Semtner & Dzator, 2025; van den Hee et al., 2025).

In this context, the study is based on the assumption that STEM education may indirectly, yet substantially, influence different types of unemployment through its role in skill formation and development, thereby affecting job matching efficiency and the alignment between labor supply and labor demand.

Although there are studies examining the relationship between STEM education and unemployment, limited attention has been given to how STEM education may be perceived to affect different types of unemployment. This highlights the need to investigate the perspectives of teachers who have received STEM education. Within this theoretical framework, the primary aim of the study is to explore, based on the views of STEM-educated teachers, which types of unemployment are most likely to be influenced by STEM education.

Literature review

The types of unemployment and the connection to STEM education

In this study, the relationship between STEM education and types of unemployment was investigated. For this purpose, some concepts need to be known. Some of these concepts are structural unemployment, voluntary and involuntary unemployment, hidden unemployment, technological unemployment, natural unemployment, real wage unemployment, and frictional unemployment.

It is possible to find many subdivisions and causes of unemployment. For example, in the 1920s, Rueff's law argues that the persistence of unemployment is caused by chronic, conjunctural, and technological reasons (Prat, 2015). The fluctuation of economic growth leads to changes in the level of individual subjective well-being (Hongo et al., 2020). This situation affects the quality of life of individuals and may cause cyclical unemployment. Although the foundations of cyclical and technological unemployment were laid in the 1920s, there have been differences in the types of unemployment over time. After the 1970s, the existence of hidden unemployment became clearer and the need to measure hidden unemployment was constantly on the agenda (Suárez-Grimalt et al., 2022). Hidden unemployment is a situation in which an individual appears to be working but is not doing any work and is not producing any product.

Technological unemployment is when people lose their jobs because of technological innovation (Swanepoel, 2023). Another type of unemployment that is indirectly affected by technological unemployment is natural unemployment. The long-term and stable equilibrium level of the unemployment rate due to structural factors such as demographics, technological innovation, and labor market actors is called the natural rate of unemployment (Li et al., 2021). Any employment or unemployment policy will not cause deviations from the natural rate of unemployment eventually. In the economic literature, the natural rate of unemployment is obtained by summing the rates of structural unemployment and frictional unemployment. Frictional unemployment is the situation in which an individual remains unemployed in the interim period between leaving one job and taking another. This situation can sometimes occur when leaving one sector and moving to another, or as a result of changing jobs while migrating from one country to another (Ikhenaode & Parello, 2020). Structural unemployment, on the other hand, can occur in the labor market because of demographic characteristics in the economy, skill mismatch, or other structural reasons affecting the labor market (Y. Liu, 2022). Voluntary unemployment is a type of unemployment that occurs when individuals quit their jobs because they do not want to work and look for another job. Recently, individuals may engage in job search activities to work in mixed part-time jobs because they want to work not only in one job but also in other jobs (W. Liu, 2023). This may lead to involuntary unemployment and real wage unemployment.

When the literature is examined, the effects of STEM education on unemployment types have not been encountered in previous studies. However, from the results of some studies, indirect effects on unemployment types can be discussed. In the labor market, if individuals are not satisfied with their current jobs, they may increase unemployment by engaging in new job search activities. This can be associated with frictional unemployment encountered during job changes. Sassler et al. (2017) concluded that in some countries, women with STEM degrees find it easier to get a job for the first time. This can be interpreted as frictional unemployment being lower for women in these countries thanks to STEM. Werum et al. (2020) investigated the advantages and disadvantages of STEM education for women in military service in the labor market after military service. They concluded that women who received STEM education after military service were more advantageous in finding a job. This shows that women with STEM education are more advantageous in combating frictional unemployment. The possibility of finding a job in a short time may decrease the rate of frictional and involuntary unemployment. There are studies in the literature that reach conclusions from this perspective.

Individuals who receive STEM education in undergraduate life have better economic rights after graduation, and career gains are realized more easily (Melguizo & Wolniak, 2012). STEM education can also be effective in academic career steps (Lawrence et al., 2014). In addition, STEM education contributes to the development of professional competencies in many fields (Sánchez Carracedo et al., 2018). Izzo and Bauer (2015) found that disabled employees with STEM education are in a more advantageous position in the labor market. Wright and Ellis (2019) found that individuals with STEM education can migrate more easily in the labor market and can be employed more easily in the labor market. From this information, it is possible to conclude that STEM education reduces frictional unemployment. Cech and Blair-Loy (2019) concluded in their study that after STEM education, parents will more easily transition to part-time employment after having children. They also found that parents have less difficulty in academic careers and are promoted more easily because of STEM education.

Knapton (2019) argues in his study that with STEM education, engineers needed especially in the manufacturing industry will be trained more easily and employed more easily. Black et al. (2021) concluded that individuals who take mathematics-based courses meet the characteristics sought by the labor market more easily and are more easily integrated into the changing conditions of the labor market. Martínez Oquendo et al. (2022) argued that individuals with STEM education have an advantageous situation in mentoring programs after university and can be employed more easily. In addition, thanks to STEM education, it is also possible to conduct remote mentoring, i.e., e-mentoring activities (Redmond & Gutke, 2020). These studies support the idea that STEM education will create effects that reduce the frictional and cyclical unemployment rate.

Upon a comprehensive review of the existing literature, one may encounter studies positing that STEM education's influence on the labor market may not be as substantial. Glass et al. (2023) contends that if gender and race variables systematically diverge in internship experiences or job search processes, corresponding disparities in the employment outcomes of individuals with STEM education are likely to ensue. Boyd and Tian (2018) assert that in certain nations, individuals with STEM education exhibit elevated rates of employment within STEM fields, particularly in developed countries. Conversely, in some regions, these individuals find employment in non-STEM occupations. This shows that STEM education does not have the same value and characteristics in all parts of the world. Therefore, STEM education may not always and under all circumstances reduce frictional unemployment. According to Salzman and Lieff Benderly (2019), there are enough STEM graduates in the

United States. Therefore, there is a possibility that STEM graduates may easily remain unemployed in the future.

According to Smith & White (2019), most STEM graduates in the UK are not employed in highly skilled STEM jobs. This may lead to the conclusion that the content of education is incompatible with market expectations. This may indirectly lead us to conclude that individuals with STEM education can seek new jobs because of low wages and that STEM education increases real wage unemployment. However, the common opinion in the literature is that STEM education will have a positive effect on the labor market.

STEM education actively fosters the cultivation of a more skilled society, instilling career aspirations among individuals. This active engagement in education contributes significantly to the augmentation of employment opportunities and the overall development of the economy (Stiles-Clarke & MacLeod, 2018). Bacovic et al. (2022) note that although the contribution of STEM graduates to economic growth in Europe has seen a relative increase, their prevalence within the population has concurrently diminished. Firms employing individuals with STEM education exhibit heightened levels of innovation, enabling them to effectively compete in the private sector and thereby contribute substantively to economic growth (Brunow et al., 2018). Such innovative firms demonstrate resilience against cyclical problems, experiencing minimal adverse impacts.

As the body of research on STEM education expands, so too do the evolving realms of its application. Notably, critical employment roles within the health sector, such as nursing, can be encompassed within the framework of STEM employment as STEM education continues to advance (Green & John, 2020). The development of STEM job opportunities in such sectors is anticipated to facilitate a more straightforward job search for individuals possessing STEM education. Consequently, this trend is poised to mitigate the effect of cyclical fluctuations on the employment status of individuals with STEM education.

Despite the rapid penetration of technology and digitalization in all sectors of the economy, people with STEM education do not have a sufficient share in the employment sector (Piątkowski, 2020). For this reason, it is important to study the relationship between STEM education and technological unemployment and identify the aspects in which it fails. Rodríguez-Pose and Lee (2020) found that STEM education alone is not sufficient for jobs that require technological knowledge, and that STEM education should be supported by innovation in individuals. The current scenario underscores the realization that STEM education, in isolation, may not constitute a comprehensive solution for alleviating technological unemployment. Harrigan et al. (2021) observed a growth in technology-related occupations within the labor market, facilitating the relatively easier employment of individuals possessing STEM education in such roles. Consequently, it is deduced that STEM education holds the potential to mitigate technological unemployment. Lysenko and Wang (2023) posit that STEM education plays a pivotal role in fostering collaboration between universities and industries, thereby fostering the generation of novel employment opportunities. An examination of the outcomes of these studies implies that STEM education is poised to exert a positive influence on the reduction of technological unemployment.

Methodology

This study used a structured qualitative design with content analysis to examine teachers' perceptions of the reflections of STEM education on types of unemployment.

Participants

Participants in the study consisted of 45 teachers who attended and successfully completed the STEM Teacher Training Program in June 2023. This training is an 80-h applied training. The maximum diversity sampling technique, which is a purposive sampling technique, was used to select the participants. This sampling method reflects the diversity of the participants as much as possible. For this purpose, participants were selected by considering gender, age, seniority, achievement, industry, and school type. Participants were given a 50-minute explanatory and comparative training on unemployment and types of unemployment by an academician specializing in employment. It should be noted that this training may have influenced participants to reflect the information provided rather than their own subjective experiences. Therefore, the findings should be interpreted in light of this limitation. Although participants are STEM-trained teachers, their expertise in economics, labor markets, and macroeconomic models is limited. Hence, their evaluations of unemployment types reflect informed perceptions rather than professional economic analysis. Demographic information about the teachers is presented in Table 1.

Table 1. Demographic Information of the Teachers

Categories	Groups	f
Gender	Female	27
	Male	18
Experience	1-10	27
	11-20	14
	21 years and over	4
Institution where he/she works	Public school	39
	Private school	6

Data collection tool and collection of data

A structured interview form served as the instrument for collecting research data. Following a comprehensive literature review to scrutinize the purpose and scope of the research, the researchers actively designed the interview form. The structured interview form, containing both closed and open-ended questions, was designed to collect perceptions rather than in-depth subjective experiences. Therefore, the study's methodology is more aligned with structured qualitative research and content analysis rather than phenomenology. To ascertain the content validity of the interview form, the researchers sought the opinions of two faculty members renowned for their expertise in employment and STEM subjects. Subsequent to the finalization of the interview form, the researchers, along with a design expert, actively approved its applicability. A link facilitating access to the form was then disseminated to the participants via email. The interview form was distributed to 50 participants engaged in STEM teacher training, with a three-day response window provided. At the conclusion of this period, the number of respondents was determined to be 38. Participants received a reminder email, granting an additional two days for response before rendering the interview form inaccessible on the website. Furthermore, participants were limited to a singular access attempt to the link from the same device. The researchers, through consensus, excluded the forms of three non-responders and two respondents with suboptimal completion from the dataset. The decision was made to incorporate the responses of 45 individuals who effectively completed the interview form into the analysis process.

The interview form contains 11 optional and 11 open-ended questions. At the beginning of each question, a short reminder about the type of unemployment was added. An example of a question used in the final interview form is presented below:

Voluntary unemployment: This is a situation in which individuals who supply labor do not take advantage of the current job position and do not voluntarily take a job in order to reach better working conditions and better wages because they find working conditions poor or current wages low. In simpler terms, it is when the worker does not work voluntarily.

What is the effect of STEM education on voluntary unemployment? Choose: (1) decreases; (2) does not affect; (3) increases.

How do you think STEM education can affect voluntary unemployment? Explain.

During the data collection process, the researchers avoided manipulating the participants' perspectives and ensured that the research process and data collection occurred objectively.

Analysis of the data

In the research, the content analysis technique was preferred to reveal the themes and dimensions in the related subject. Word processing and spreadsheet tools were used to analyze the data. First, all data in the Internet environment were transferred to the word processing program. Before the analysis, the main dimensions of the employment variable were identified as reducing unemployment, not affecting unemployment, and increasing unemployment. An attempt was made to explain the data by creating sub-themes under the three main themes because of content analysis.

Reliability and validity

Several procedures were employed to ensure the validity and reliability of the study findings. Qualitative data obtained from the interview questions were independently coded by two experts specializing in STEM education and workforce studies. Inter-coder reliability was calculated by dividing the number of agreements by the total number of coding decisions, resulting in a reliability coefficient of **0.87**, which indicates a high level of coding reliability. To minimize potential researcher bias and strengthen internal validity, the coding and theme development processes were carried out independently by experts working in separate locations.

Findings

Within the scope of the research, before asking questions to STEM-trained teachers, the meaning of each type of unemployment was explained with examples. Teachers were asked about the possible effects of STEM education on these types of unemployment and their reasons, and their responses are summarized in Table 2.

Table 2. Effect of STEM education on the types of unemployment

The type of Unemployment	Reduces Unemployment		No Effect on Unemployment		Increases Unemployment	
	N	%	N	%	N	%
Voluntary Unemployment	21	48.84	15	34.88	7	16.28
Involuntary Unemployment	40	90.90	1	2.27	3	6.81
Frictional Unemployment	35	81.40	4	9.30	4	9.30
Structural Unemployment	34	77.27	3	6.82	7	15.91
Cyclical Unemployment	34	77.27	9	20.45	1	2.27
Real wage unemployment	21	48.84	17	39.53	5	11.63
Hidden Unemployment	32	74.41	7	16.28	4	9.30
Technological Unemployment	32	71.11	-	-	13	28.88
Seasonal Unemployment	32	71.11	7	15.55	6	13.33
Natural Unemployment	20	44.44	24	53.33	1	2.22

The relationship between receiving STEM education and types of unemployment is grouped into three main categories: decreasing unemployment, having no effect on unemployment, and increasing unemployment. Participants indicated that STEM education would generally reduce the number of types of unemployment. When analyzing Table 2, STEM education is believed to reduce involuntary unemployment the most (>90%). Participants indicated that STEM education would have more difficulty solving natural, real wage, and voluntary unemployment than other types of unemployment. The participants were asked about the reasons for their answers, and the results of the analysis are presented under the appropriate headings.

Findings on the effect of STEM education on voluntary unemployment

Participants were asked how STEM education might affect voluntary unemployment. Participant opinions are presented in Table 3.

Table 3. Effect of STEM Education on Voluntary Unemployment

Effect Type	Effect Source
Reduces voluntary unemployment.	Qualified employee Entrepreneurship and Individual Innovation Current competencies
Does not affect voluntary unemployment.	Unchanged working conditions
Increases voluntary unemployment.	High wage demand Reduced need for physical manpower

18% of respondents stated that STEM education would reduce voluntary unemployment. STEM education will reduce voluntary unemployment because of the increase in qualified personnel because of this education. In addition, the increase in entrepreneurship, individual innovation, and current skills with this education will contribute to the decrease in voluntary unemployment. The opinions of some participants on this issue are as follows:

> *"With STEM, qualified personnel will increase and will be paid what they think they deserve."*
> *"Entrepreneurship and innovation skills can enable individuals to have more freedom to start their own business or explore alternative career paths."*
> *"Thanks to STEM training, people will gain high-level thinking skills such as problem solving, knowing what they want, creative thinking, observing, predicting, questioning, and exploring. Thus, they will start to evaluate their current working conditions and look for ways to have better conditions."*

Those who stated that STEM education would not affect voluntary unemployment stated that the reason for this was that working conditions did not change. The opinion of a participant on this issue is as follows:

> *"I think it does not. Because if the working conditions are not suitable, individuals may not want to work."*

Those who stated that STEM education will increase voluntary unemployment cited the higher wage demands of qualified workers and the decrease in the need for physical manpower. The opinions of some participants about these are as follows:

> *"Since they will be better equipped with STEM education, they can promote themselves better and demand higher wages."*
> *"The need for human beings will decrease even more by making productions with robots produced with STEM education."*

Findings on the effect of STEM education on involuntary unemployment

Participants were asked about the effect of STEM education on involuntary unemployment. Participant opinions are presented in Table 4.

Table 4. Effect of STEM Education on Involuntary Unemployment

Effect Type	Effect Source
Reduces involuntary unemployment.	Qualified employee
	Increased production
	Entrepreneurship and Individual Innovation
	Interdisciplinary skill acquisition
Increases involuntary unemployment.	Tendency to be selective

The majority of respondents (91%) stated that STEM education will reduce involuntary unemployment. STEM education reduces involuntary unemployment because of the increase in the number of qualified personnel because of this education. In addition, it was stated that the increase in production, entrepreneurship, individual innovation, and the acquisition of interdisciplinary skills will contribute to the reduction of involuntary unemployment. The views of some participants on this issue are as follows:

> *"I think that STEM education will reduce involuntary unemployment as it increases the skills of the person and occurs in the professions of the future."*

"I think that STEM education will reduce involuntary unemployment as production-oriented brains are trained."
"They can create suitable job opportunities for themselves and open their own businesses through entrepreneurship."
"Since there is an integration of different disciplines in STEM education, the individual will easily find a job suitable for his/her own ability."

Findings on the effect of STEM education on fractional unemployment

Participants were asked about the effect of STEM education on frictional unemployment. Participant opinions are presented in Table 5.

Table 5. Effect of STEM Education on Fractional Unemployment

Effect Type	Effect Source
Reduces frictional unemployment.	Ability to find a job easily
	Adaptability
	Lifelong learning
Does not affect frictional unemployment.	Not mentioned by participants
Increases frictional unemployment.	New job preparation process

The majority of respondents (81%) said that STEM education would reduce frictional unemployment. STEM education will reduce frictional unemployment because of the increase in the number of people who, because of this education, have gained the ability to find a job easily, have high adaptability, and are open to lifelong learning. The opinions of some participants on this issue are as follows:

"I think that it will also reduce frictional unemployment as it will provide the opportunity to find a job in a shorter time."
"Since STEM will increase adaptability, the frictional period will decrease."
"STEM education will definitely reduce frictional unemployment. Because individuals are self-improved, open to development, and equipped with the necessary equipment."

Those who stated that STEM education would increase frictional unemployment stated that the reason for this was the process of preparation for a new job. The opinion of a participant about this is as follows:

"I think it partially increases the type of unemployment during job change. If those who receive this training want to change jobs, they may need more time with more learning and research instincts.

Findings on the effect of STEM education on structural unemployment

Participants were asked about the effect of receiving STEM education on structural unemployment. Participant opinions are presented in Table 6.

Table 6. Effect of STEM Education on Structural Unemployment

Effect Type	Effect Source
Reduces structural unemployment.	Technology adaptation Personal development in different areas Openness to innovation
Increases structural unemployment.	Reduced need for manpower

The majority of the participants (77%) stated that STEM education would reduce structural unemployment. The reason why STEM education reduces structural unemployment is mostly stated as the adaptation of individuals to technology. In addition, the personal development of individuals in different fields and their openness to innovation were stated as the reasons why STEM education would reduce structural unemployment. The opinions of some participants about this are as follows:

> *"STEM education increases the number of individuals who keep up with technology, which reduces structural unemployment."*
> *"STEM education definitely reduces structural unemployment. Because it is aimed to bring individuals who train themselves in the field and who are the pioneers of continuous change and development into business life."*
> *"STEM education is an educational approach that fits and adapts to the process. People who receive education always renew themselves and are open to innovations. Therefore, structural unemployment will decrease."*

Those who stated that STEM education will increase structural unemployment stated that the reason for this is the decrease in manpower-based jobs. The opinion of a participant about this is as follows:

> *"STEM education makes daily life easier. Therefore, the need for manpower can turn to technology. The work done by a few workers today can be done easily and regularly thanks to robots."*

Findings on the effect of STEM Education on cyclical unemployment

Participants were asked about the effect of STEM education on cyclical unemployment. Participant opinions are presented in Table 7.

Table 7. Effect of STEM Education on Cyclical Unemployment

Effect Type	Effect Source
Reduces cyclical unemployment.	21st century skills Versatile element Economic stability
Does not affect cyclical unemployment.	Multifaceted factors affecting the economy

The majority of respondents (77%) indicated that STEM education reduces cyclical unemployment. The most commonly cited reason for STEM education reducing cyclical unemployment is that individuals have 21st century skills. In addition, the reasons for reducing cyclical unemployment were cited as individuals being versatile workers and STEM education providing economic stability throughout the country. Some of the participants' views on this issue are as follows:

> *"Since STEM involves 21st century skills such as problem solving and creative thinking, it will be quick to get out of such crises."*
> *"STEM education will have a positive impact on this field as it will affect the development of individuals in many areas."*
> *"STEM education will provide stability in economic fluctuations as it affects all areas of society with individuals trained in every field."*

Those who said STEM education would not affect cyclical unemployment cited various factors affecting the economy. Here is one participant's opinion:

> *"It may not be able to influence economic fluctuations alone. Because there are many internal or external factors affecting this area."*

Findings on the effect of STEM education on real-wage unemployment

Participants were asked about the effect of STEM education on real wage unemployment. Participant views are presented in Table 8.

Table 8. Effect of STEM Education on Real Wage Unemployment

Effect Type	Effect Source
Reduces real wage unemployment.	Qualified employee
	Increased production
Does not affect real wage unemployment.	Multifaceted economy
Increases real wage unemployment.	Expectations of high wages

48% of respondents said that STEM education would reduce real wage unemployment. The reason why STEM education will reduce real wage unemployment is to train skilled personnel and increase production. Some of the participants' opinions on this are as follows:

> *"I think the best people will work in the field and will look for more than one feature in people."*
> *"STEM Education can reduce this type of unemployment because it encourages production and creates projects that can meet the need for production."*

Those who stated that STEM education would not affect real wage unemployment stated that this was because the economy is multifaceted. The opinion of a participant about this is as follows:

> *"I think the change in real wages is related to the policy of the country. Therefore, I think STEM education cannot affect real wage unemployment."*

Those who stated that STEM education would increase real wage unemployment stated that the reason for this was the expectation of high wages. The opinion of a participant about this is as follows:

> *"I think that STEM education will have a negative impact as it will increase the expectation of satisfactory real wages."*

Findings on the effect of STEM education on hidden unemployment

Participants were asked about the effect of receiving STEM education on hidden unemployment. Participant opinions are presented in Table 9.

Table 9. Effect of STEM Education on Hidden Unemployment

Effect Type	Effect Source
Reduces hidden unemployment.	Increased production Arousing a desire to work
Does not affect hidden unemployment.	Not mentioned by participants

The majority of respondents (74%) said that STEM education would reduce hidden unemployment. The reason why STEM education will reduce hidden unemployment is the increase in production and the desire of individuals to work. Some of the participants' opinions on this are as follows:

"STEM education reduces hidden unemployment. STEM training ensures the formation of productive individuals."

"People intend to be active employees instead of being hidden unemployed."

Findings on the Effect ***of STEM education on technological unemployment***

Participants were asked about the effect of STEM education on technological unemployment. Participant opinions are presented in Table 10.

Table 10. Effect of STEM Education on Technological Unemployment

Effect Type	Effect Source
Technology reduces unemployment.	Being open to innovations Unity of science and technology
Increases technological unemployment.	Substitution of technology for manpower

The majority of respondents (71%) said that STEM education reduces technological unemployment. The reason why STEM education reduces technological unemployment is that because of this education, individuals are open to innovation, and science and technology are given together. Some of the participants' opinions on this are as follows:

"Since STEM education will raise individuals who renew and develop themselves according to changing situations, technological unemployment can be prevented."

"Since STEM education is intertwined with science and technology, I think it can eliminate technological unemployment."

Those who stated that STEM education will increase technological unemployment stated that the reason for this is that technology replaces human power. The opinion of a participant about this is as follows:

"The technology integration dimension of STEM education partially increases unemployment as it reduces the need for manpower."

Findings on the effect of STEM education on seasonal unemployment

Participants were asked about the *effect* of receiving STEM education on seasonal unemployment. Participant opinions are presented in Table 11.

Table 2. Effect of STEM Education on Seasonal Unemployment

Effect Type	Effect Source
Reduces seasonal unemployment.	Versatile skills Increased production
Does not affect seasonal unemployment.	Not mentioned by participants
Increases seasonal unemployment.	Substitution of technology for manpower

The majority of respondents (71%) said that STEM education reduces seasonal unemployment. The reason why STEM education reduces seasonal unemployment is that because of this education, individuals gain versatile skills and production increases. Some of the participants' opinions on this are as follows:

> *"It will create versatile skills due to multifaceted education."*
> *"Especially if modern agricultural practices are introduced with STEM trainings, production areas in the agricultural sector can gain continuity. Thus, seasonal unemployment based on agriculture will decrease."*

Those who stated that STEM education will increase seasonal unemployment stated that the reason for this is the substitution of technology for manpower. The opinion of a participant about this is as follows:

> *"It can increase seasonal unemployment. The construction of vehicles for which manpower is not required could lead to the replacement of humans by machines."*

Findings on the effect of STEM education on natural unemployment

Participants were asked about the effect of STEM education on natural unemployment. Participant opinions are presented in Table 12.

Table 3. Effect of STEM Education on Natural Unemployment

Effect Type	Effect Source
Reduces natural unemployment.	Qualified employee Providing new job opportunities
Does not affect natural unemployment.	General policy
Increase natural unemployment.	Not mentioned by participants

44% of respondents stated that STEM education will reduce natural unemployment. They stated that the reason why STEM education reduces natural unemployment is that because of this education, they are trained as qualified personnel, and they have new job opportunities thanks to the education they receive. The opinions of some participants on this issue are as follows:

> *"Since STEM will make society more qualified in every aspect, it will reduce the reasons for unemployment."*
> *"STEM education can positively affect this field. Thanks to the products made with STEM education, new job opportunities can be opened and unemployment in these fields can be prevented."*

Those who stated that STEM education would increase natural unemployment stated the reason for this as the policies implemented. The opinion of a participant about these is as follows:

"STEM education will not impact natural unemployment due to public policies and the increase in structural unemployment."

Discussion and conclusion

In this study, teachers who received STEM education stated that STEM education can generally have a positive effect on employment. This is related to the fact that STEM education tries to meet the needs of the business world (Yıldırım et al., 2022) and aims to provide resources for some technology-intensive job positions (Akcan et al., 2023). Similarly, there are studies showing that STEM education will increase employment (Stiles-Clarke & MacLeod, 2018). In addition, studies that conclude that STEM education reduces gender inequality in the labor market (King Miller, 2017; Osei-Kofi & Torres, 2015; ltzer & Smith, 2014) also support this finding.

Participants' views are that STEM education will mostly reduce involuntary and frictional unemployment, individuals with STEM education are more effective in their careers (Lawrence et al, 2014; Melguizo & Wolniak, 2012), are more easily employed in the labor market (Wright & Ellis, 2019), are more easily promoted (Cech & Blair-Loy, 2019), and women with STEM degrees are more easily employed (Martínez Oquendo et al., 2022; Werum et al., 2020; Knapton, 2019; Sassler et al., 2017).

The views of most of the participants that STEM education will reduce technological unemployment agree with the finding of Harrigan et al. (2021) that individuals with STEM education can be employed more easily. On the other hand, in the research, the opinion that STEM education will increase technological unemployment the most among the types of unemployment was dominant. This finding agrees with the findings that technological innovations cause unemployment (Swanepoel, 2023; Li et al., 2021; Prat, 2015), individuals with STEM education cannot get enough share in the field of employment (Piątkowski, 2020), and STEM education alone cannot be sufficient in jobs where technological knowledge is required (Rodríguez-Pose & Lee, 2020).

Some individuals and organizations argue that the development of technology and the replacement of humans by machines cause cyclical changes and increase unemployment. The fact that STEM education includes "technology" supports the view that it will reduce cyclical and structural unemployment in this research finding by facilitating easy adaptation to change and innovation.

The view of most participants that STEM education will not reduce voluntary and real wage unemployment is consistent with the knowledge that economic growth causes changes in individual welfare levels (Hongo et al., 2020). As individual welfare levels increase, so do the rates of job aversion and labor force non-participation. The fact that most STEM graduates do not work where they want to (Smith & White, 2019) may increase voluntary and real unemployment.

Most participants believe that STEM education will not reduce natural unemployment. On the basis of the analysis of the literature and the views of the participants, it is predicted that natural unemployment can only be partially reduced by major policy changes on a global or local scale.

In conclusion, in this study, in which the possible effects of STEM education on types of unemployment were determined, it was found that the opinions of teachers who received STEM education were toward increasing employment. However, to increase this level to a higher level, it is important that STEM education is carried out by considering the needs of society. Since STEM education produces skilled individuals who are open to lifelong learning, innovation, and cooperation, it is concluded that it will reduce involuntary, frictional, cyclical, and structural unemployment. In addition, this study has some limitations. The research is limited to the views of teachers who are experts in STEM education from a qualitative perspective. The research only collected data from teachers who received STEM education. Collecting data from employees and experts of employment and job placement agencies may contribute to the generalizability of the findings. Comparing the unemployment status of individuals with and without STEM education at the end of the educational process may be beneficial in terms of seeing the results in practice. Since the effect of STEM education on employment varies depending on the country context (Boyd & Tian, 2018), similar studies should be conducted in countries with different levels of development to generalize the findings obtained. The findings of this study may be useful in developing policies, especially in minimizing the problem of unemployment.

Recommendations and limitations

Based on the findings obtained from teachers who received STEM education and a brief training on the labor force and types of unemployment, recommendations have been developed to further investigate the effects of STEM education on labor force participation, employment, and different types of unemployment. To examine the direct and indirect impacts of STEM education on different types of unemployment more comprehensively, future research should not be limited to teachers' perspectives but also include the views of students, employers, employees, and policymakers. In addition, mixed-method research designs could be employed to compare qualitative findings with labor force, unemployment rate, and unemployment type data. To observe the practical effects of STEM education, comparative studies could be conducted analyzing the labor market participation and unemployment experiences of individuals who have received STEM education versus those who have not.

It should be noted that this study was conducted within certain limitations. The study only included teachers who received STEM education and a brief seminar on unemployment types. The participants' responses reflect the perceptions of individuals trained in STEM rather than professional labor market analyses. A prior training session on unemployment types may have influenced participants' responses. Finally, since the study relied on qualitative methods and content analysis, statistical generalizations cannot be made.

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