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ARAB HIGHER EDUCATION SCIENCE STUDENTS' PERCEPTIONS OF TECHNOLOGY-ENHANCED INNOVATIVE SCIENCE TEACHING AND ITS INFLUENCE ON THEIR SCIENTIFIC PATHWAY CHOICES

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Abstract:
This article examines how Arab higher education science students perceive the technology-enhanced innovative teaching methods used by their secondary school science teachers and how these experiences influenced their decisions to pursue scientific pathways. It starts from the view that students' choices of scientific pathways cannot be explained by grades, family expectations, or labor-market considerations alone. These choices are also shaped by the quality of classroom pedagogy, the encouragement students receive from teachers, the way technology is integrated, and the gradual development of a science identity. The study used a qualitative research design. Data were collected through semi-structured interviews with 30 Arab students enrolled in science-related programs in higher education, including biology, chemistry, physics, medicine, pharmacy, nursing, computer science, engineering, and related fields. The interviews were analyzed thematically in relation to innovative science teaching, technology-enhanced learning, motivation, self-efficacy, science identity, and contextual challenges in Arab education. The interviews show that students often described secondary school as a turning point when science moved from memorized information to active inquiry, experimentation, digital visualization, and project-based learning. Technology was perceived as valuable when it made invisible scientific processes visible, supported experimentation, or enabled data collection and analysis. However, students repeatedly emphasized that the teacher's role was more important than the digital tool itself: effective teachers used technology to ask questions, encourage inquiry, normalize mistakes, and build confidence. They also show that successful school science experiences strengthened motivation, self-efficacy, and a sense of belonging to science, thereby influencing students' academic choices. At the same time, students did not ignore the limits of their school context. They identified barriers such as limited laboratory resources, unequal technological infrastructure, pressure from matriculation examinations, insufficient exposure to academic scientific language, and gaps between Arab schools and better-resourced schools. The article concludes that technology-

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enhanced innovative science teaching can support Arab students' entry into scientific pathways when it is implemented as a meaningful pedagogical practice embedded in supportive teacher-student relationships and culturally responsive school environments.

Keywords: Arab students, science education, technology-enhanced learning, innovative teaching, STEM pathways, science identity, motivation, self-efficacy, higher education, qualitative research

1. Introduction

Science education is now one of the main pathways through which young people gain access to higher education, professional opportunities, technological participation, and social mobility. In societies increasingly organized around knowledge, technology, and innovation, scientific fields such as medicine, engineering, computer science, biotechnology, chemistry, physics, and environmental science are closely connected to innovation and economic development. For Arab students in Israel and in comparable minority contexts, entry into scientific pathways may also carry broader meanings related to representation, empowerment, community contribution, and the desire to overcome structural barriers. Understanding why students decide to pursue science therefore requires attention to the educational experiences that precede higher education. The article focuses on Arab students who are currently enrolled in scientific fields in higher education. It examines how they remember and interpret the science teaching methods they experienced in secondary school, especially methods they perceived as innovative and enhanced by technology. The analysis is based on the assumption that students' previous school science experiences are not neutral memories; rather, they may become formative experiences that influence motivation, confidence, self-perception, and future choice. A student who experiences science only through memorization may develop a very different relationship to science than a student who experiences inquiry, experimentation, problem solving, simulation, and teacher encouragement.

In many classrooms, science teaching still emphasizes explanation, textbook knowledge, definitions, formulae, and preparation for examinations. These approaches may provide necessary foundations; however, they may also distance students from the investigative nature of science. In contrast, innovative science teaching seeks to engage learners in asking questions, testing hypotheses, designing models, conducting experiments, using evidence, discussing explanations, and applying knowledge to real-world problems. Such teaching is consistent with constructivist perspectives, which view learning as an active process of meaning-making rather than passive reception of information (Bruner, 1961; Piaget, 1952; Vygotsky, 1978).

Technology-enhanced learning adds a further layer to this process. Digital simulations, virtual laboratories, animations, smart screens, data sensors, videos, programming environments, and online inquiry tools can help students visualize scientific phenomena that are difficult to observe directly. For example, molecular movement, cellular division, chemical bonds, electric circuits, physical forces, and ecological processes may become more accessible when students interact with visual and dynamic representations. Yet the interviews make one point very clear: technology alone does not create innovation. Its value depends on the teacher's pedagogical use of it, the questions asked, the tasks designed, and the opportunities students receive to participate actively.

This issue is particularly important in the context of Arab science education. Participants repeatedly referred to contextual challenges such as unequal resources, limited laboratory equipment, old or crowded laboratories, pressure from matriculation examinations, and the need to move between Arabic, Hebrew, and English scientific terminology. These realities show that the question is not simply whether technology is used in science classrooms, but whether it is used in ways that expand opportunities, reduce barriers, and help students imagine themselves as legitimate participants in scientific fields.

The main research question guiding the study is: How do Arab higher education science students perceive the technology-enhanced innovative teaching methods used by their secondary school science teachers, and how have these experiences influenced their decisions to pursue scientific pathways? The sub-questions examine how students describe innovative teaching methods, how they perceive technology integration, how these experiences influenced motivation, how they contributed to science identity, how they affected decisions to study science in higher education, and what contextual factors facilitated or hindered these processes.

The contribution of this article lies in its focus on students who have already crossed the boundary from school science into higher education science. Their narratives provide insight into the classroom experiences that remained meaningful after graduation. Their accounts can inform teachers, school leaders, policymakers, curriculum designers, and teacher educators who seek to increase Arab students' participation in scientific fields. Rather than treating science pathway choice as an individual decision alone, the study shows that it is shaped by pedagogical, relational, technological, cultural, and structural factors.

2. Literature Review

2.1 Constructivist and Innovative Science Teaching

Innovative science teaching is closely connected to constructivist theories of learning, which emphasize that learners build knowledge through interaction with ideas, materials, peers, teachers, and meaningful problems. Piaget (1952) highlighted the active role of the learner in constructing cognitive structures, while Vygotsky (1978) emphasized the social and cultural dimensions of learning, including the role of guidance, language, and interaction. Bruner (1961) argued that discovery and inquiry can support deeper understanding, especially when students are encouraged to explore relationships and principles rather than receive ready-made answers.

In science education, constructivist teaching often appears through inquiry-based learning, project-based learning, problem solving, laboratory work, group investigation, modeling, and reflective discussion. Brooks and Brooks (1999) argued that constructivist classrooms should encourage students to question, interpret, and connect knowledge to prior understanding. Bransford, Brown, and Cocking (2000) similarly emphasized that meaningful learning requires connecting new knowledge to existing ideas and engaging learners in active thinking. This is particularly relevant to science, where concepts are frequently abstract and where misconceptions can persist if students do not actively reconstruct their understanding.

In this study, students' descriptions of meaningful science lessons reflected these principles. They remembered lessons in which teachers did not simply provide the answer but asked "why," "how do you know," and "what do you expect?" They also described projects, experiments, group work, and research tasks that required investigation rather than memorization. Their narratives suggest that innovative teaching was experienced not as a set of isolated techniques, but as a change in the student's role: from receiver of information to participant in scientific thinking.

2.2 STEM Education and Integrated Learning

STEM education emphasizes the integration of science, technology, engineering, and mathematics in ways that prepare students to solve complex problems. Honey, Pearson, and Schweingruber (2014) described STEM integration as an educational approach that can connect disciplinary knowledge with authentic problem-solving. Ortiz-Revilla, Greca, and Arriassecq (2022) argued that integrated STEM requires a coherent theoretical framework because meaningful integration involves more than placing the four disciplines side by side. Baptista, Jacinto, and Martins (2023) also emphasized the importance of explanation in integrated STEM learning, suggesting that students need opportunities to justify, connect, and communicate scientific reasoning.

Research has shown that STEM activities can influence students' attitudes, motivation, science process skills, and career interests. Guzey, Moore, Harwell, and Moreno (2016) found that STEM integration in middle school life science can affect learning and attitudes, while Hiğde and Aktamış (2022) reported positive effects of STEM activities on STEM career interests, motivation, science process skills, achievement, and views. Batdi, Talan, and Semerci (2019), in their meta-analytic and meta-thematic review, highlighted the educational potential of STEM approaches while also pointing to the need for careful implementation.

For Arab students, integrated STEM may carry particular value because it connects science to real-life challenges, technological applications, and future professional possibilities. Several participants in the present study stated that they wished science lessons had included more programming, 3D printing, data analysis, links to high-tech, and visits to universities or industry. These recommendations indicate that students viewed science not only as school knowledge but as a bridge to modern academic and professional worlds.

2.3 Motivation, Interest, and Self-Efficacy in Science

Motivation is a central factor in science learning and in the decision to continue toward scientific fields. Expectancy-value theory suggests that students' choices are shaped by their expectations of success and by the value they attach to a subject or activity (Eccles & Wigfield, 2002; Wigfield & Eccles, 2000; Okumuş *et al.*, 2019). If students believe that they can succeed in science and that science is meaningful for their future, they are more likely to invest effort and choose science-related pathways.

Science motivation is also connected to self-efficacy, or students' belief in their ability to succeed in scientific tasks. Bandura's (1986) social cognitive theory emphasizes that self-efficacy develops through mastery experiences, social persuasion, observation, and emotional states. In science classrooms, successful experiments, supportive teacher feedback, and opportunities to present findings can become mastery experiences that strengthen students' belief in their scientific ability. Dede and Yaman (2008) highlighted the importance of motivation toward science learning, while Britner (2008) showed that motivation in high school science is connected to important differences across science domains.

Interest in science does not develop in isolation. Osborne, Simon, and Collins (2003) reviewed research on attitudes toward science and emphasized the importance of school experiences, teaching practices, and perceived relevance. In the interviews, participants repeatedly stated that their interest increased when science was connected to life, technology, medicine, energy, the environment, or community problems. This supports the idea that motivation is strengthened when students experience science as useful, understandable, and personally meaningful.

2.4 Science Identity, Aspirations, and STEM Career Choice

Science identity can be understood as the extent to which students see themselves as people who can participate in science, understand science, and be recognized by others as capable science learners. Archer, DeWitt, Osborne, Dillon, Willis, and Wong (2012) showed that science aspirations are shaped by science capital, family habitus, and identification with science. This means that students' choices are not determined only by ability; they are also shaped by whether science feels like a field where they can belong.

Social cognitive career theory also provides a useful framework for understanding science pathway choices. Lent, Brown, and Hackett (1994, 1996) argued that career interests and choices are shaped by self-efficacy, outcome expectations, goals, and contextual supports or barriers. Subsequent research has continued to examine STEM career interest among students. Chachashvili-Bolotin, Milner-Bolotin, and Lissitsa (2016) examined factors predicting secondary students' interest in tertiary STEM education, while Christensen and Knezek (2017) studied the relationship between middle school STEM interest and career intent. Maltese and Tai (2011) showed that educational experiences can be associated with persistence in STEM degrees.

Recent research also highlights the role of self-concept, perceptions of STEM professionals, and environmental factors in shaping STEM aspirations. Chen, So, Zhu, and Chiu (2024) examined STEM learning opportunities and career aspirations, while Halim, Shahali, and Iksan (2021) emphasized the mediating role of self-efficacy. Han, Kelley, and Knowles (2021) identified self-efficacy, outcome expectancy, 21st-century skills, and career awareness as factors influencing STEM learning. These studies support the present research focus on students' narratives of motivation, identity, and pathway choice.

2.5 Technology-Enhanced STEM Learning

Technology-enhanced STEM learning can expand students' access to scientific representations, inquiry tools, data collection, and digital experimentation. Peterman, Kermish-Allen, Knezek, Christensen, and Tyler-Wood (2016) studied student career interest within the context of technology-enhanced STEM projects, showing the importance of technology-rich learning environments in shaping interest. Zhao, Wijaya, Mailizar, and Habibi (2022) examined factors influencing student satisfaction toward STEM education and highlighted the multidimensional nature of STEM learning experiences.

In science classrooms, technology is especially valuable because many scientific phenomena are invisible or difficult to reproduce physically. Simulations, animations, and virtual laboratories can support conceptual understanding by allowing students to manipulate variables and observe changes. Digital sensors can connect laboratory work to real-time data analysis, while videos and interactive presentations can connect science to everyday contexts. Nevertheless, technology must be integrated pedagogically. A smart board used for passive lecture does not necessarily create innovative teaching; a simulation used within inquiry, discussion, and reflection can do so.

This distinction was visible in the interview data. Students appreciated technology when it helped them participate, search, observe, measure, analyze, and understand. They were less impressed by technology used merely as slides. This finding aligns with constructivist and STEM-oriented literature: technology is educationally powerful when it reorganizes the learning activity and expands students' participation in scientific practices.

2.6 Contextual Challenges in Arab Science Education

Arab students' movement into scientific pathways needs to be understood within wider social and educational contexts. Shinwell, Cohen, and Baruch (2021) addressed the education system as an engine for socio-economic integration of Arab society, highlighting the importance of human capital development. In the present study, participants described science education as a way to prove oneself, contribute to the community, and gain access to respected professional fields. At the same time, they identified gaps in laboratories, budgets, enrichment programs, technological infrastructure, and academic language preparation.

The STEM equity literature also shows that access to STEM opportunities is not equally distributed. UNESCO (2017) emphasized persistent gender and social barriers in

STEM education, while Chauke (2022) explored gender differences in determinants of STEM interest. Vooren, Haelermans, Groot, and Van Den Brink (2022) examined female students' success in STEM fields, showing the importance of tracking access and outcomes across time. Although the present study does not focus primarily on gender, its findings highlight broader equity concerns related to school resources and opportunities.

Students also referred to emotional barriers such as fear of failure, examination pressure, and the difficulty of entering higher education with Hebrew and English scientific terminology. Science anxiety has been discussed in research by Mallow (2006), Britner (2010), Cooper, Downing, and Brownell (2018), and England, Brigati, Schussler, and Chen (2019). These studies are relevant because several participants described how traditional memorization or exam pressure made science feel dry or frightening, while supportive inquiry-based teaching reduced fear and helped them experience mistakes as part of learning.

Based on the reviewed literature and the analytical focus of this study, Figure 1 presents the conceptual model that guided the interpretation of the findings.

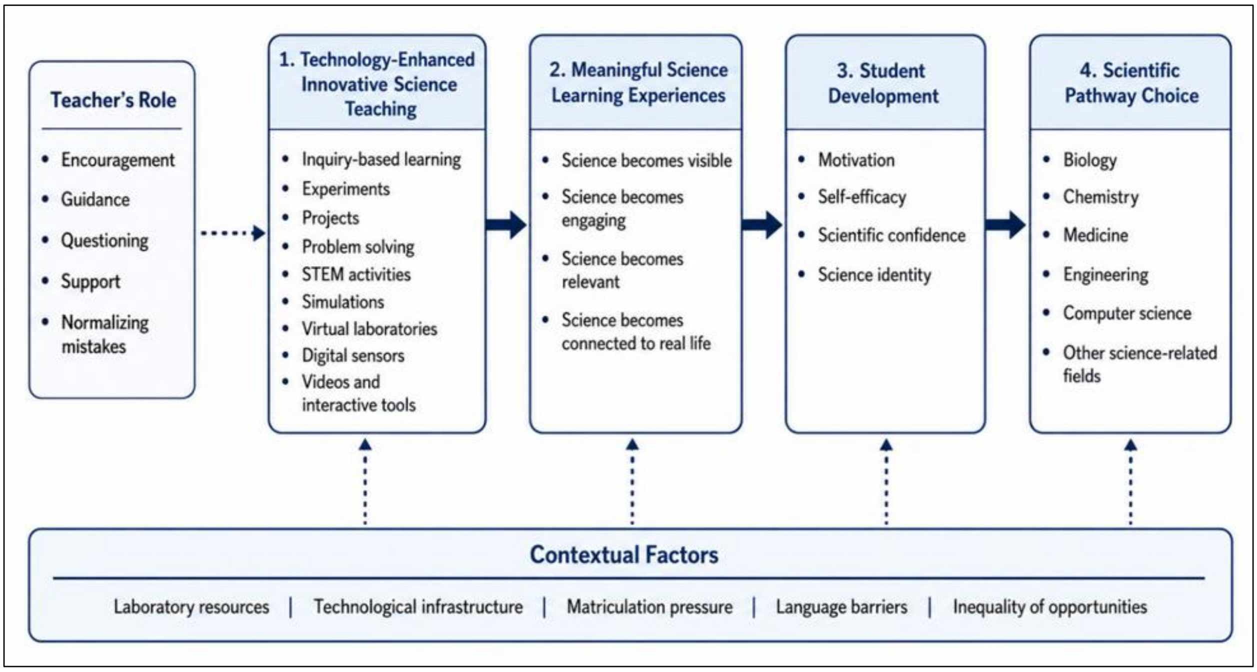

Figure 1: Conceptual model of the influence of technology-enhanced innovative science teaching on students' scientific pathway choices

As Figure 1 suggests, the relationship between innovative science teaching and later scientific pathway choice is mediated by meaningful learning experiences, students' motivation and self-beliefs, and the wider influence of teacher support and contextual conditions.

3. Material and Methods

The study employed a qualitative research design to explore Arab higher education science students' perceptions of technology-enhanced innovative science teaching and its influence on their scientific pathway choices. This approach was appropriate because the study sought to understand meanings, experiences, memories, and interpretations rather than measure predetermined variables. The research questions focused on how students describe their previous science learning experiences and how they connect these experiences to motivation, science identity, and academic decision-making.

Because the research was based on students' memories and interpretations, the analysis was also attentive to the researcher's position as a science educator. This position helped in understanding the language of science classrooms, laboratory work, and teacher-student relationships. At the same time, it required careful attention not to impose expected meanings on the participants' accounts. For this reason, the analysis stayed close to the interview transcripts and used participants' own examples whenever possible.

The population consisted of Arab students enrolled in higher education institutions and studying science-related fields. The participants represented a range of disciplines, including biology, cellular and molecular biology, chemistry, biochemistry, physics, applied physics, medicine, dentistry, pharmacy, nursing, chemical engineering, biomedical engineering, computer engineering, software engineering, computer science, information systems engineering, mathematics, and science teaching. This diversity allowed the study to explore whether similar school experiences were remembered across different scientific pathways.

The sample consisted of 30 participants who were selected purposively because they met the main criteria of the study: they were Arab students, they were studying in a science-related field in higher education, and they were able to reflect on their secondary school science experiences. Purposive sampling was appropriate because the study required participants who had direct experience with the phenomenon under investigation. The aim was not statistical representativeness but rich insight into the pathways of students who continued into science.

Data were collected through semi-structured interviews conducted in Arabic. The interview protocol included questions about participants' current studies, reasons for choosing their field, memories of science learning in middle and secondary school, teaching methods used by science teachers, integration of technology, meaningful learning experiences, development of interest, sense of belonging to science, teacher support, Arab identity, decision-making moments, strengths and weaknesses in science education, perceived equity of opportunities, and recommendations for improving science teaching in Arab schools.

Semi-structured interviews were suitable for this study because they provided a common structure while allowing participants to elaborate on their personal experiences. The interviews enabled the researcher to follow up on specific examples such as laboratory experiments, digital simulations, science projects, teacher encouragement, and university transition. The use of Arabic supported participant comfort and allowed students to express emotional and cultural meanings naturally. When excerpts were used in the article, they were translated into English while preserving the intended meaning.

The analysis followed a thematic approach. First, the transcripts were read repeatedly in order to develop familiarity with the data. Second, meaningful units related to the research questions were coded. Codes included, for example, memorization, inquiry, laboratory work, teacher encouragement, simulations, virtual labs, digital sensors, science confidence, science identity, Arab identity, language barriers, examination pressure, and resource gaps. Third, similar codes were grouped into broader themes. Finally, the themes were interpreted in relation to the theoretical framework and literature review.

Ethical considerations were maintained throughout the research process. Participation was voluntary, and participants were informed that there were no right or wrong answers. The research aimed to understand experiences rather than evaluate individuals or schools. Confidentiality was maintained by avoiding identifying details, and quotations were presented anonymously. Because participants reflected on teachers and institutions, the analysis focused on patterns and meanings rather than personal identification.

4. Results

The thematic analysis produced seven major themes. Taken together, the themes show how technology-enhanced innovative teaching methods shaped students' understanding of science, their motivation, their confidence, their developing science identity, and their decisions to pursue scientific pathways. They also show that students' experiences were shaped by the Arab educational context, including both supportive factors and structural barriers.

For clarity, the seven themes identified through thematic analysis are summarized visually in Figure 2 before they are discussed in detail. Figure 2 offers a concise overview of the themes that structure the findings section, while the following subsections return to each theme in greater depth and with illustrative quotations from participants.

The themes are presented separately for analytical clarity, but in the interviews they often overlapped. For example, students usually spoke about technology together with teacher encouragement, or about laboratory work together with confidence and belonging. This overlap is important because it reflects how students actually experienced science learning: as a connected set of classroom, emotional, and social experiences rather than as isolated factors.

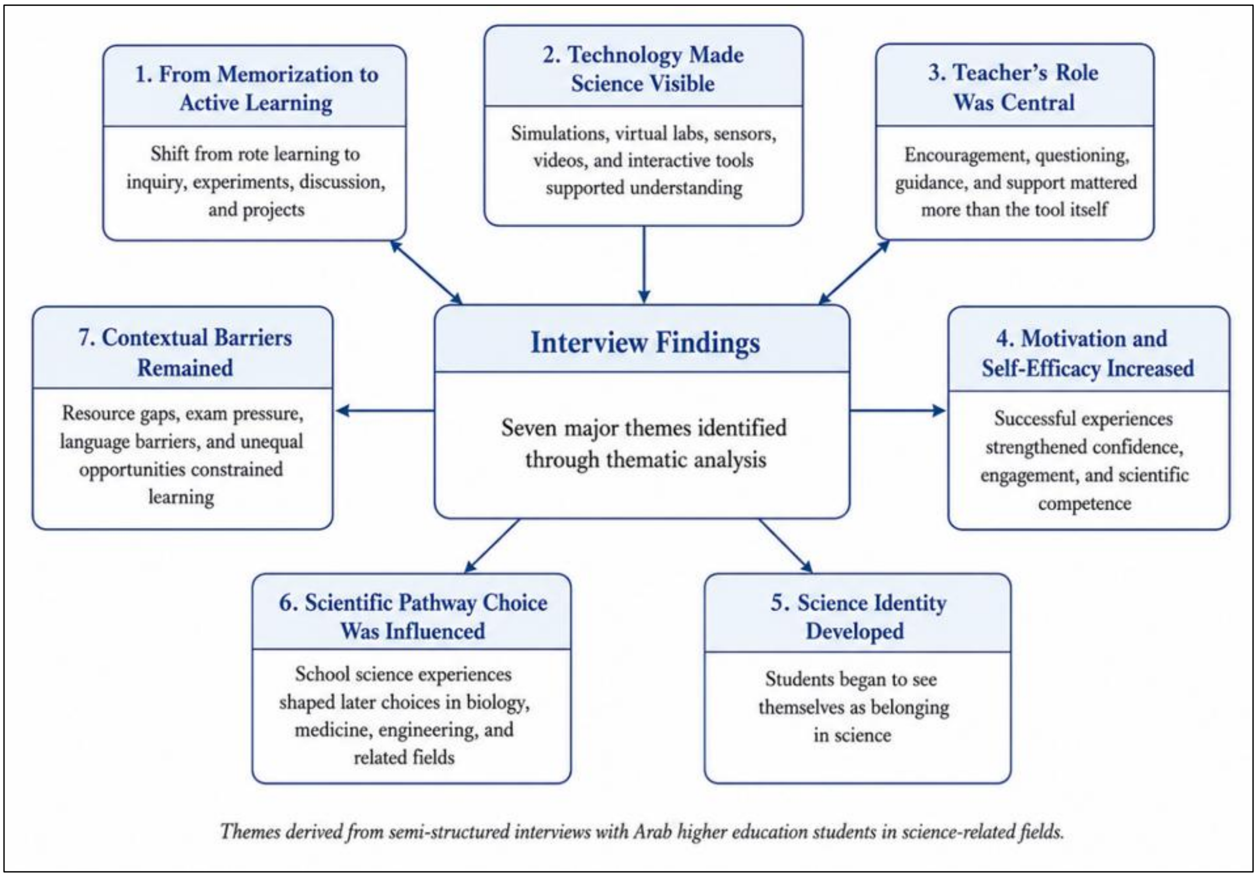

Figure 2: Main themes emerging from the interviews

Theme 1: From Memorization to Active and Inquiry-Based Science Learning

Many students described a clear contrast between earlier science learning, especially in middle school, and later experiences in secondary school. Middle school science was often remembered as traditional, based on teacher explanation, copying, memorization, and preparation for tests. In contrast, secondary school was frequently described as a turning point because it included experiments, inquiry, discussion, projects, and opportunities to think scientifically. One biology student stated that in middle school the experience "*depended on memorization*," while in secondary school the lessons became "*interactive workshops full of discussions and practical experiments.*" Another student explained that when science was connected to experience, observation, and technology, it became more meaningful and closer to him.

Students did not reject explanation or theoretical foundations. Rather, they valued the combination of brief explanation with active investigation. Students reported that teachers who began with a question, a problem, a surprising demonstration, or a real-life phenomenon encouraged them to think rather than memorize. Several students described teachers who asked them to predict results before experiments, interpret outcomes, and discuss why something happened. This changed the classroom from a place where knowledge was delivered to a place where students participated in producing understanding.

> *"In middle school, the experience was very traditional and depended on memorization. In secondary school, it became a turning point; lessons became interactive workshops full of discussion and practical experiments."* (Participant, biology; translated from Arabic)

Theme 2: Technology Made Scientific Processes Visible, Concrete, and Engaging

Technology was one of the clearest recurring themes in the interviews. Participants described the use of simulations, virtual laboratories, animations, smart screens, digital sensors, computer-based graphs, videos, online resources, and interactive presentations. Students in biology described animations of cellular processes, DNA replication, cell division, and microscopic structures. Students in chemistry and chemical engineering described three-dimensional molecular simulations, digital pH sensors, and graphs that appeared on computer screens during titration experiments. Students in physics and engineering referred to circuit-building software, Arduino, robotics, and data analysis tools.

A biology student explained that technology made science "*visible and alive*," because he no longer read about DNA as an abstract concept but saw it represented in simulations. A chemistry student described a titration experiment in which the color changed at a specific point while a pH graph appeared on the screen, saying that the moment felt "*like magic, but based on science*." Another participant emphasized that technology should not be used merely as slides, but as a tool that makes students participate, interact, and search.

These accounts indicate that technology was valued most when it helped students understand phenomena that could not be seen directly. The data also suggest that technology helped bridge theory and practice. Students did not experience simulations as a replacement for experiments; rather, they often valued the combination of simulation and laboratory work. For example, a biology student described first using a digital simulation to understand DNA extraction steps and then moving to the laboratory to extract DNA from a strawberry. This sequence helped the student connect digital visualization with physical observation.

> *"Technology made science clearer and closer. But it should not be only slides; it should be a tool that makes the student participate, interact, and search."* (Participant, science student; translated from Arabic)

> *"The moment the color changed, and the pH graph appeared on the screen, I felt it was like magic, but magic built on science."* (Participant, chemical engineering; translated from Arabic)

Theme 3: The Teacher's Pedagogical Role Was More Important Than the Tool Itself

One finding stood out strongly: that participants did not attribute their motivation to technology alone. Instead, they repeatedly emphasized the science teacher's role. Teachers were described as facilitators, encouragers, guides, and confidence-builders.

Students admired teachers who asked questions instead of giving answers, allowed mistakes, encouraged experimentation, connected science to daily life, and believed in students' potential. One participant stated that his biology teacher was a "*facilitator and not only a transmitter of information*." Another student remembered a teacher who said that mistakes in the laboratory teach more than correct answers in the textbook.

The emotional side of teacher support appeared strongly in the data. Several students described specific words of encouragement that remained with them for years. A chemical engineering student recalled that his teacher told him, "*You have an engineering mind, and the Technion suits you*," a statement that helped him set the Technion as a goal while still in grade eleven. A nursing or medical student similarly described how teacher encouragement and family support strengthened the belief that she could enter a demanding scientific field.

These findings indicate that technology-enhanced teaching is not primarily a technical practice. It is a relational and pedagogical practice. A digital simulation becomes meaningful when the teacher uses it to ask questions, guide observation, and invite interpretation. A laboratory experiment becomes formative when the teacher creates a safe space for mistakes and reflection. Students remembered not only what tools were used but how teachers made them feel: capable, curious, and legitimate as science learners.

> *"The teacher's encouragement was more important than the academic explanation itself. She made me feel that I could succeed in science."* (Participant, biology; translated from Arabic)

Theme 4: Successful Experiences Strengthened Motivation, Self-Efficacy, and Scientific Confidence

Many participants connected innovative teaching methods to motivation and confidence. Experiments, projects, and technology-supported activities helped students feel that science was understandable and achievable. Students described moments in which they succeeded in explaining a project, observing a microscopic structure, analyzing data, or solving a problem. These moments functioned as mastery experiences that strengthened self-efficacy.

A student who participated in a science fair described standing before judges and explaining a project on water purification, stating that he felt like "a young scientist." Another student said that participating in a small scientific project and successfully presenting it to classmates made him feel that he not only understood science but could also explain and convince others. A biology student recalled examining onion cells under a microscope and seeing the nucleus and cell wall, describing the experience as a moment in which she felt like a real researcher discovering something for the first time.

Students also emphasized that their motivation increased when science was connected to real problems. Water purification, pollution, biodiversity, epidemiological simulations, and medical applications made science feel socially relevant. Students reported that such experiences moved science beyond examination preparation and made it appear as a way to solve problems in the community and the world. This relevance was especially important for students who wanted careers that combine scientific knowledge with social contribution.

> *"When I stood there explaining the scientific principles of my project to the judges and the audience, I felt like a young scientist and not only a student receiving information."* (Participant, cellular and molecular biology; translated from Arabic)

Theme 5: Development of Science Identity and Belonging

The interviews suggest that technology-enhanced innovative teaching contributed to the development of science identity for many participants. Science identity appeared when students began to see themselves not only as students learning science but as people who could belong to scientific fields. This sense of belonging was often connected to participation in research projects, laboratory reports, science fairs, biotop projects, matriculation research assignments, or university visits.

For example, one biology student described presenting a research project for the matriculation requirement and defending his results before a committee. In that moment, he said, he felt that he belonged to the scientific world. A chemical engineering student described a school visit to the Technion laboratories as a turning point, saying that when he saw students working with large equipment, he thought, "*In a few years I will be here too*." A biomedical engineering student described school projects as the foundation that later prepared him for project-based learning at university.

The data show that science identity developed through three repeated mechanisms: competence, recognition, and imagination. Competence emerged when students successfully performed scientific tasks. Recognition emerged when teachers, peers, or examiners treated them as capable. Imagination emerged when students could see a future self in a scientific field. Technology and innovative pedagogy supported these mechanisms by providing students with experiences that resembled authentic scientific practice.

> *"When I presented my research and defended my results, I felt that I belonged to this world."* (Participant, biology; translated from Arabic)

Theme 6: Influence on Scientific Pathway Choice

Most participants described a strong relationship between the teaching methods they experienced and their current academic choices. They were careful not to claim that teaching methods were the only factor. Family support, personal interests, grades, future employment, professional status, and community need also mattered. Nevertheless, school science experiences were repeatedly described as the place where interest became clearer and where abstract curiosity became an academic direction.

A chemical engineering student stated that if his teacher had taught chemistry only from the book through memorization, he would not have considered chemical engineering. A biology student explained that school transformed childhood curiosity into a clear academic pathway. A computer engineering student explained that project-based learning in secondary school was directly connected to the project-based environment he later encountered at Tel Aviv University. A medical student described case-study learning in biology as a foundation for medical thinking, because doctors also move from symptoms to diagnosis through evidence.

These accounts suggest that innovative science teaching contributed to pathway choice by changing students' images of science. Science became a field of action, inquiry, problem solving, design, and social contribution. Technology helped students see the modern face of science, while teachers helped them believe that they could enter that world. In this sense, teaching methods did not merely support achievement; they shaped students' academic imagination.

> *"If my teacher had taught chemistry only from the book and through memorization, I would never have thought of continuing to chemical engineering."* (Participant, chemical engineering; translated from Arabic)

Theme 7: Contextual Barriers and Inequality of Opportunities

Alongside these positive experiences, participants identified significant barriers. The most common barriers were limited budgets, insufficient laboratory equipment, crowded or old laboratories, unequal access to technological tools, and pressure from matriculation examinations. Some students stated that they heard about advanced equipment but could see it only in videos because their school did not have it. Others described laboratories in which large groups had to share equipment, limiting the opportunity for each student to work directly with materials.

Language also appeared as a major barrier. Several participants emphasized that secondary school science was mainly learned in Arabic, while higher education required Hebrew and English scientific terminology. Students recommended that schools gradually expose learners to Hebrew and English scientific terms, academic articles, and technical English. One participant stated that learning technical English is essential, while another wished that school had trained students to read scientific articles in Hebrew and English before university.

Participants also discussed unequal opportunities between schools. Some schools had advanced laboratories, robotics, STEM programs, and connections with universities or research institutes, while others lacked basic materials. Students argued that equity in science education is not achieved simply by teaching the same curriculum; it requires giving every student a real opportunity to experiment, use technology, receive support, and participate in enrichment. These comments show that students understood science education as a matter of educational justice as well as pedagogy.

> *"Educational opportunities are not equal. Some schools have advanced laboratories, STEM programs, and scientific competitions, while other students do not receive the same opportunities."* (Participant, science student; translated from Arabic)

5. Discussion

The findings suggest that Arab higher education science students perceive technology-enhanced innovative science teaching as a significant factor in shaping their motivation, confidence, science identity, and scientific pathway choices. The study does not present a simple causal relationship in which technology automatically leads to science careers. Rather, it shows a more complex process: innovative teaching methods created meaningful experiences; technology made science visible and interactive; teachers transformed these experiences into confidence and belonging; and these processes interacted with family, grades, aspirations, and contextual barriers.

The first point to discuss concerns the shift from memorization to active learning. Participants repeatedly described traditional science lessons as dry, boring, or focused on examinations, while active lessons were remembered as turning points. This supports constructivist learning theory, which emphasizes that students build understanding through active engagement (Bruner, 1961; Piaget, 1952; Vygotsky, 1978). The students' narratives also reflect the importance of meaningful learning, in which new concepts are connected to prior experiences and real-life contexts. Their most memorable lessons were not necessarily the most advanced but those in which they could see, touch, test, discuss, or apply scientific ideas.

A second point concerns technology. The findings align with research on technology-enhanced STEM projects and STEM learning opportunities (Peterman *et al.*, 2016; Zhao *et al.*, 2022; Chen *et al.*, 2024). Technology supported understanding when it visualized invisible processes, enabled data collection, or helped connect simulation with laboratory work. However, the findings also warn against superficial integration. Participants clearly distinguished between meaningful technology use and passive presentations. This suggests that teacher professional development should focus not only on operating digital tools but on designing inquiry-oriented technology-enhanced learning tasks.

A third point concerns is the central role of the teacher. Students' decisions to pursue science were shaped by teachers who believed in them, encouraged them, and created safe learning environments. This finding is consistent with Bandura's (1986) understanding of self-efficacy, because verbal encouragement and successful experiences can strengthen students' belief in their abilities. It is also consistent with expectancy-value theory (Eccles & Wigfield, 2002; Wigfield & Eccles, 2000), because teachers helped students both expect success and value science as meaningful for their future.

A fourth point concerns science identity. The data indicate that identity developed when students experienced themselves as participants in scientific practices. Presenting a project, defending results, using digital tools, or conducting a laboratory investigation helped students imagine themselves as future scientists, doctors, engineers, programmers, or teachers. This supports Archer *et al.* (2012), who emphasized that science aspirations are connected to identification with science and science capital. In the present study, school experiences helped students accumulate a form of science capital through participation, recognition, and exposure to scientific futures.

A fifth point concerns scientific pathway choice. Participants' stories align with social cognitive career theory, which argues that career choice is shaped by self-efficacy, outcome expectations, goals, and contextual supports and barriers (Lent *et al.*, 1994, 1996). Students chose scientific fields because they liked science, succeeded in science, saw future value in science, and received support. Yet barriers such as language, resources, and exam pressure also influenced the process. Therefore, science pathway choice should be understood as both personal and structural.

A sixth point concerns the Arab educational context. Students framed science not only as a school subject but also as a way to prove capability, support community progress, and enter respected professions. This finding is important because it suggests that science identity among Arab students may include collective and social meanings. Students did not speak only about individual success; they also spoke about becoming doctors, engineers, researchers, teachers, and professionals who can contribute to Arab society. This aligns with discussions of education as a route for socio-economic integration and human capital development (Shinwell *et al.*, 2021).

The final point concerns equity. Participants' recommendations were practical and systemic: update laboratories, provide virtual laboratories and digital platforms, train teachers, reduce overreliance on examinations, integrate programming and data analysis, expose students to universities and industry, and support academic language preparation. These recommendations show that students see innovation not as a luxury but as a condition for fair opportunity. If only some schools have access to advanced laboratories, robotics, STEM enrichment, or university connections, then science pathway choice is shaped by unequal opportunity structures.

Overall, this article contributes to the literature by showing how Arab students who actually entered scientific fields interpret their school science experiences retrospectively. Their accounts demonstrate that technology-enhanced innovative teaching can become a formative influence when it is embedded in active pedagogy, teacher support, and meaningful contexts. At the same time, the study shows that innovation must be supported structurally. Teachers cannot be expected to transform science education without time, training, resources, and institutional support.

6. Conclusion

This article examined Arab higher education science students' perceptions of technology-enhanced innovative science teaching and its influence on their decisions to pursue scientific pathways. Based on semi-structured interviews with 30 students in science-related programs, the study found that innovative teaching methods contributed to students' understanding, motivation, self-efficacy, science identity, and academic decision-making. Participants repeatedly described secondary school as a turning point when science became active, visible, meaningful, and connected to future possibilities.

The findings suggest that inquiry-based learning, projects, experiments, simulations, virtual laboratories, digital sensors, videos, and interactive tools can make science more engaging and understandable. However, the study also found that technology is not enough by itself. The teacher's role was central. Teachers who encouraged students, normalized mistakes, asked open questions, connected science to life, and believed in students' abilities had a lasting influence on students' confidence and pathway choices.

The study also highlights the development of science identity. Students began to see themselves as capable science learners when they participated in authentic scientific activities such as experiments, research projects, science fairs, laboratory reports, and technology-supported investigations. These experiences allowed students to imagine future selves in medicine, engineering, biology, physics, chemistry, computer science, pharmacy, nursing, dentistry, and science teaching.

At the same time, the interviews brought out contextual challenges in Arab science education. These included unequal resources, limited laboratories, old equipment, crowded laboratory spaces, lack of advanced digital tools, examination pressure, limited professional guidance, and linguistic challenges in the transition to higher education. These barriers show that improving science education requires systemic investment, not only individual teacher effort.

The article recommends strengthening professional development for science teachers in Arab schools, especially in inquiry-based learning, project-based learning, technology integration, STEM pedagogy, and culturally responsive teaching. Schools should receive better laboratory infrastructure, access to virtual laboratories, digital sensors, and platforms that support experimentation and data analysis. Students should be gradually exposed to Hebrew and English scientific terminology and to academic scientific texts in order to ease the transition to higher education. Career guidance should also be expanded through meetings with scientists, engineers, doctors, pharmacists, programmers, and university students.

Future research could examine differences according to gender, discipline, school type, socioeconomic background, or geographic area. Quantitative or mixed-methods studies could measure relationships between exposure to technology-enhanced innovative teaching, science self-efficacy, science identity, and STEM pathway choice. Longitudinal studies could also follow students from secondary school into higher education in order to understand how motivation and identity change over time.

These accounts also suggest a practical responsibility. If schools want more Arab students to enter scientific fields, they need to offer more than curriculum coverage. They need to offer experiences through which students can see science, practice science, speak science, and gradually recognize themselves as people who can belong to science.

Ultimately, the study reminds us that students' scientific futures begin in school classrooms. A single experiment, a successful project, a teacher's encouragement, a digital simulation, or a visit to a university laboratory can become a turning point in a student's life. For Arab students, meaningful science education can be a path not only to academic success but also to belonging, empowerment, and contribution to society.

Conflict of Interest Statement

The author declares no conflicts of interest.

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