

A Study of the Impact of the International Physics Olympiads on School Students

Akniyet Issain

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Department of Pedagogy of Natural Sciences

Thesis Supervisor:
PhD, Associate Professor, Samat Maxutov

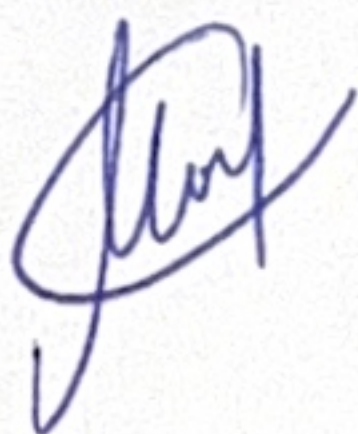
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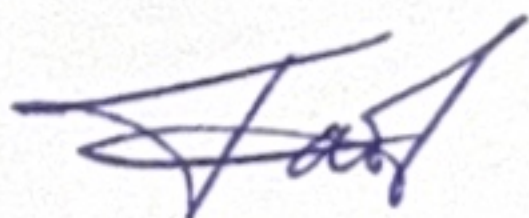
Approved by

Thesis Supervisor



PhD, Associate Professor SDU,
Samat Maxutov

M.Ed.Program Coordinator



MSc, Ayatola Gabdulin

Head of Department of
Natural Science Pedagogy



PhD, Associate Professor,
Zhangyl Abilbek

Dean of School



PhD, Assistant Professor,
Dana Moldabayeva

Kaskelen, 2026

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List of abbreviations

ANOVA	Analysis of Variance
df	Degrees of Freedom
IChO	International Chemistry Olympiad
IJSO	International Junior Science Olympiad
IPhO	International Physics Olympiad
ISO	International Science Olympiad
IZhO	International Zhautykov Olympiad
M	Mean
N	Number of participants
p	Probability value / significance level
SD	Standard Deviation
SE	Standard Error
STEM	Science, Technology, Engineering, and Mathematics
t-test	Statistical test used to compare the means of two groups
VET	Vocational Education and Training

Abstract

The skills and knowledge gained through participation in international physics Olympiads are a main point of analysis of this thesis. The role of Olympiad learning as an effective way of promoting higher order thinking skills and a positive orientation to a future career in science has received increasing attention. Nevertheless, there is little empirical evidence of its impact on students' competencies and aspirations, particularly in the case of Kazakhstan.

To bridge this gap, a mixed-methods approach was used to collect quantitative data with a structured survey adopting pre-tested standardized instruments for measuring 21st century skills and career aspirations, and qualitative data to triangulate, validate, and provide a deeper context of the quantitative findings. Students who had previously participated in international physics Olympiads were included in the study. Descriptive statistics, independent samples t-tests, and one-way ANOVAs were used to analyze gender, age, and school type differences between students in the study.

Keywords: International Physics Olympiad, International Zhautykov Olympiad, STEM education, science Olympiads, 21st-century skills, skill development, career aspirations.

Аннотация

В данной диссертации основное внимание уделяется навыкам и знаниям, полученным в результате участия в международных олимпиадах по физике. Роль олимпиадного обучения как эффективного способа развития навыков мышления высокого уровня и формирования позитивной ориентации на будущую карьеру в науке привлекает все больше внимания. Тем не менее, существует мало эмпирических данных о его влиянии на компетенции и стремления учащихся, особенно в случае Казахстана.

Для восполнения этого пробела был использован смешанный подход к сбору количественных данных: структурированный опрос с использованием предварительно протестированных стандартизированных инструментов для измерения навыков XXI века и карьерных устремлений, а также качественные данные для триангуляции, проверки и более глубокого контекста количественных результатов. В исследование были включены учащиеся, ранее участвовавшие в международных олимпиадах по физике. Для анализа различий по полу, возрасту и типу школы между учащимися, участвовавшими в исследовании, использовались описательная статистика, t-критерий для независимых выборок и однофакторный дисперсионный анализ.

Ключевые слова: Международная олимпиада по физике, Международная олимпиада Жаутыкова, STEM-образование, научные олимпиады, навыки XXI века, развитие навыков, карьерные устремления.

Аннотация

Халықаралық физика олимпиадаларына қатысу арқылы алынған дағдылар мен білім осы диссертацияны талдаудың негізгі мәселесі болып табылады. Олимпиадалық оқытудың жоғары деңгейлі ойлау дағдыларын дамытудың және болашақ ғылым мансапына оң бағдар берудің тиімді тәсілі ретіндегі рөлі барған сайын назар аударылуда. Дегенмен, оның оқушылардың құзыреттіліктері мен ұмтылыстарына, әсіресе Қазақстан жағдайында, әсерінің эмпирикалық дәлелдері аз.

Бұл алшақтықты жою үшін сандық деректерді жинау үшін аралас әдістер қолданылды, олар 21 ғасырдағы дағдылар мен мансаптық ұмтылыстарды өлшеуге арналған алдын ала тексерілген стандартталған құралдарды және сандық нәтижелерді триангуляциялау, растау және тереңірек контекст беру үшін сапалық деректерді қолдана отырып, құрылымдық сауалнаманы қолданды. Зерттеуге бұрын халықаралық физика олимпиадаларына қатысқан оқушылар енгізілді. Зерттеудегі оқушылар арасындағы жыныс, жас және мектеп типіндегі айырмашылықтарды талдау үшін сипаттамалық статистика, тәуелсіз үлгілер, t-тесттер және бір жақты ANOVA қолданылды.

Түйінді сөздер: Халықаралық физика олимпиадасы, Халықаралық Жаутықов олимпиадасы, STEM білімі, жаратылыстану олимпиадалары, 21 ғасырдағы дағдылар, дағдыларды дамыту, мансаптық ұмтылыстар.

1 Introduction

1.1 Background of the study

Amid rapid innovation and globalization, STEM education and training has become a global priority, where economies are increasingly driven by innovation, scientific research and development, engineering, and technological development. STEM skills development continues to be stressed in education systems around the world. Education systems and governments have given priority to developing not only subject knowledge, but also other types of competencies that enable students to cope with complex and uncertain situations, and thus better prepare students for the future. The skills referred to as 21st-century skills include critical thinking and problem solving, communication, collaboration, creativity, and digital literacy.

Consequently, these skills are no longer perceived as optional. They need to become an integral part of academic success and professional development. While the customary format of teaching has helped students develop a basic understanding, it does not always provide them with adequate opportunities to practice higher-order thinking and transfer of knowledge. Therefore, educational alternatives are increasingly proposed which ease active learning, independence and experiential problem solving.

One of the best methods of improving STEM skills outside of the normal curriculum is academic competition. Science Olympiads are competitions in which students can learn and show their own knowledge of scientific and mathematical concepts through advanced intellectual activities that require greater analysis and problem solving in their respective fields. These competitions give students the chance to work independently, to challenge their abilities, and to compete at a high academic level. They also provide students with the opportunity to meet other students from different educational systems and cultural backgrounds from across the country.

Students who participate in these competitions have been found to be more motivated, have higher academic self-esteem, and persist for longer in solving complex problems than their peers who do not participate in Olympiads. Likewise,

these can impact students' attitudes towards STEM education, or their ambitions to pursue further study or careers in these areas. In addition, early exposure to more advanced scientific concepts and problem-solving approaches may also stimulate students towards career paths such as engineering, scientific research, or technical professions.

International Zhautykov Olympiad (IZhO) is an international Olympiad for high school students. It is one of the major international Olympiads intended to stimulate the development of gifted schoolchildren in the field of mathematics, physics and informatics - the leading sciences that determine the development of science and technology. The problems given on the theoretical and experimental levels of the IZhO exceed the basic school curriculum, and require a high level of reasoning ability, synthesis of knowledge in a number of subjects, and a high level of mental ability on the part of the participant.

Also different from other standardized tests, Olympiads such as the IZhO have a focus on creativity, originality, and an in-depth understanding of concepts; the ability to apply knowledge to new and unexplored problems; and the ability to communicate complex and detailed ideas in a clear and logical manner. Together, these factors give rise not just to knowledge in a particular subject, but a transferable skill set that includes logical thinking, creativity and communication.

Also, students who take part in international competitions are exposed to competitive environments which may help them in real life to develop good time management skills, the ability to work under pressure, maintain focus for long periods, and develop self-regulation and resilience. Students also work with other students in the preparation stage, developing teamwork and socialization skills.

Despite the importance of Olympiad participation, there is limited research regarding its educational impact in many areas. Research on Science Olympiads has generally focused on the effect of participation on academic performance or motivation, but some research has focused on how students perceive that participation to affect their learning (e.g., 21st-century skills). These self-perceptions are important

because they influence students' confidence, engagement, and decisions about their long-term education pathways.

Another factor that may need to be considered is the role of individual and contextual factors in competing at the Olympiads. The students may differ by gender, age, academic specialization and educational background, all of which may have an impact on the students' experience. For example, previous literature has indicated that there may be differences between male and female students in their confidence, interest, and participation in science, as well as in the availability of resources, training, and support for students from different types of schools, which could in turn affect their performance in science education.

In addition to this, age of the students themselves can influence how their participation is viewed, with younger students benefiting more from the novelty of participating, and older students taking a more mature approach. Perhaps counter intuitively, even repeated participation in Olympiads can be helpful or detrimental to the students depending on their experiences. Some students may benefit from repeating participation while others outgrow their interest.

One way to further examine this question is to conduct a multivariate analysis, which is a statistical technique that looks at how different variables, such as Olympiad participation, may affect the development of certain skills and career aspirations across different types of students. This analysis may also help identify gaps or inequalities in opportunity that could inform more inclusive educational strategies.

Thus, the objective of the present study is to find out the extent to which participation in the International Zhautykov Olympiad influences students' self-perception of their development of 21st century skills and interest in STEM subjects. Furthermore, factors such as gender, age, subject of specialization, type of school, and frequency of participating in the competition will also be taken into account.

1.2 Statement of the Problem

Despite their reputation as valuable educational experiences, there is still limited empirical evidence of international Olympiads' impact on fostering skills and aspirations of students, especially in the case of the International Zhautykov Olympiad.

Research to date has mostly used general skills such as academic achievement and motivation. Less is known about how students interpret the development of specific skills and the role of demographic and contextual factors in this development. Less is known about the effects of students' gender, age, subject specialization, school type, and participation frequency on their experience and perceived outcomes.

Furthermore, treatment effects for each subsequent Olympiad are often omitted in the literature. Thus, the treatment effect of participation across years is not well-studied. By failing to investigate the long-term impact of Olympiad participation compared to merely exposing the educational leaders and policymakers with the findings of a particular Olympiad year, the literature misses the chance to provide them details for creating a strong program.

Therefore, the research problem addressed in this study is the lack of research on the impact of participation in IZhO on participants' perceptions of 21st-century skill learning and STEM career aspirations among different participant groups.

1.3 Objectives of the Study

The aim of this study is to investigate the effect of participation in the International Zhautykov Olympiad on the students' perception of skill development and pursuing STEM careers.

The specific objectives are:

To check for differences in perceived skill growth,

To contrast among the STEM subject specializations

To explore whether age affects online skill development perceptions

To compare the perceived advantages of different school types

To measure the effect of frequency of participation on skill

1.4 Significance of the Study

The findings can contribute to the STEM education literature that investigates how academic competition experiences can influence the development of 21st century skills and students' career interest. As the demand for innovation and highly-skilled workers in the science and technology fields continue to rise, the impact of educational experiences such as competitions on student development is important to explore.

In the theoretical segment, the proposed research will contribute to the existing literature through narrowing the various fields of interest to only the International Zhautykov Olympiad, which has not been studied yet. The literature on Science Olympiads is largely general and lacks focus on how individual competitions relate to students' perceptions of their success. By addressing this, this study contributes to the understanding of how structured academic competitions for students can act as learning environments.

From the pedagogical perspective, the results of the study may help a teacher to understand the effect of Olympiad participation on different student categories and to design curricula to include Olympiad-like problem solving in the classroom or successful preparation for the Olympiad. Problem solving of complex, non-routine problems may engage the students and help develop their analytical skills.

The results of this study could have important implications for schools to best provide for students who participate in academic competitions through the provision of training materials, mentorship, and the establishment of structured preparation programs. The identification of differences by school type can help address inequality of access to opportunities.

The results of this study may also inform educational policy-makers. The results of this research suggest that Olympiad participation is associated with increases in STEM skills and interest in a STEM career, indicating that competition-based instruction should be included in wider STEM education practices. The study's findings could be useful to policymakers in the design of programs aimed at promoting equitable access to academic competitions for varied racial and ethnic groups.

The findings of this study also suggest the potential utility of considering a wide variety of demographic and contextual factors (such as gender and age of the participants) in the design of educational interventions, as these factors may help to maximize the possible benefits of participation for all students.

The article concludes with results of the study and the understanding of non-formal educational environments as a supplement to formal teaching. The types of learning experiences gained in attending Olympiads and the importance of extracurricular activities in developing competencies for a contemporary knowledge society are discussed.

1.5 Limitations of the Study

Nevertheless, this study has some limitations that should be considered when interpreting its results.

The first limitation of this study is its cross-sectional study design. A cross-sectional design collects data at one point in time which provides associations between variables, but not cause and effect relationships. This means that it is impossible to determine causality. Consequently, it is difficult to conclude with certainty that Olympiad participation has a direct effect on improvement or the pursuit of related careers.

Second, the data for this study were collected through self-reported questionnaires. Self-reported measures can potentially capture the participants' perspectives and experiences but are vulnerable to bias in their responses. Participants' perception of skills developed in the program may not be accurate, because self-reported findings can be compromised by social desirability, peer comparison, or personal level of confidence in their ability.

In addition, the sample size used in the study and its scope are also limitations. The study used students that have participated in the International Zhautykov Olympiad as their sample. This means that the study is limited to students who are high achievers, and the results may not necessarily apply to students who do not participate in academic competitions. There is also a possibility of unequal representation of

certain groups (e.g. gender, school type, ethnicity) among the participants in each treatment group.

Another concern is that convenience sampling is likely to suffer from selection bias, if those opting to answer the survey are in some way systematically different from those who did not.

The study also does not measure the actual acquisition of skills (through performance measures) or the longitudinal academic achievements of students, leaving the question of whether perceived skills actually correlate with skill performance unanswered. Future research may consider combining self-reported and objective measures to overcome this limitation.

Other factors which could have been investigated for their role in developing skills and choice of career such as socio-economic background, quality of training received, mentoring received during training, and prior educational attainment, were not examined in this thesis and may also have a meaningful impact.

Acknowledging these limitations also provides a balanced perspective on the findings and indicates the need for further research in this area.

1.6 Overview of the International Zhautykov Olympiad (IZhO)

The International Zhautykov Olympiad (IZhO) is an annual international competition for high school students gifted and talented in Mathematics, Physics and Informatics. The Olympiad is aimed at promoting development of scientific education in all countries of the world and promoting participation and achievement at scientific Olympiads.

One of the largest regional international olympiads is the IZhO. Each year, students from specialized secondary schools, national teams, and specialized schools teach gifted youth in the IZhO. The Olympiad intends to identify the most promising students, to encourage study in the sciences, and to promote international cooperation among younger mathematicians.

One distinguishing feature of the IZhO is that its problems are advanced. Olympians must work through a number of theoretical problems which go beyond the

high school curriculum, and experimental problems which test not only their understanding of physics but also their dexterity and practical ability, in the case of physics. The problems of the IZhO are different from standard school tests, requiring students to think independently, apply their knowledge in a new situation and find original solutions.

Each Olympiad subject is typically divided into several rounds. The problems are set by subject specialists, designed to test students in depth and in novelty. In the physics Olympiad, students are typically tested in both theoretical problems and experimental investigations. This dual format enables such testing to provide a fuller picture of students' skills in reasoning, care, and the interpretation and use of physical phenomena.

Competitors in the IZhO are generally trained through courses specifically designed for the event, their team leaders, and practice. Students selected to represent their countries typically go through a national or regional competition, ensuring that the final representatives are well-prepared and highly motivated to compete. For this reason, the level of education and competition is high in classes or sections of students, called the IZhO.

Apart from gaining academic knowledge, the IZhO program also offers students opportunities for cultural exchange and socializing with peers from different backgrounds, as well as sharpening their communication skills. The work at IZhO also contributes to the development of learners' cognitive and non-cognitive skills, including cooperation, adaptability and intercultural awareness.

In terms of IZhO, this study is relevant as it provides a field where higher-order learning, advanced problem solving, competition and internationalization go hand in hand. It is a unique place where students are challenged to reach their maximum potential and at the same time develop skills which are transferable to many areas. This is a context within which to consider the effect of Olympiad participation on students' perception of their skills and their interest in pursuing STEM careers.

In addition, a focus on the IZhO allows the current study to fill a gap in the literature on the topic, as prior literature on Science Olympiads has not limited itself to the general category, and there is a dearth of literature that employs the approach taken by the current study of examining an experience in a specific Science Olympiad such as the IZhO.

2 Literature Review

2.1 Science Olympiads in STEM Education

Science Olympiads continue to be an important part of modern STEM (Science, Technology, Engineering, and Mathematics) education, and are used to identify academically gifted students, and provide them with an opportunity to learn advanced materials outside the classroom. These competitions are intended to further develop problem-solving skills through non-routine, high-level problems which require the application of knowledge creatively and the exercise of persistence. Because of this they are often not viewed just as competitions, but as educational activities that help students develop intellectually and personally.

Another important part of Science Olympiads is the development of talent. Lim et al. (2014) note that national and international Olympiad systems are often used as structured mechanisms to identify students with extraordinary abilities in scientific disciplines. Besides the experience gifted students have to improve their problem solving abilities, the evidence of an association between participation in such competitive events and improved achievement is positive. Campbell and Tirri (2017) state that participation in Olympiads supports the development of intellectual curiosity, perseverance and motivation. Thus, these findings suggest that Olympiads are an important factor in the formation of scientists.

In addition to identifying extraordinary talent, Science Olympiads are believed to help advance conceptual understanding, as competition tasks require participants to integrate several different topics and to apply their knowledge in new contexts, rather than simply reproducing the application of standard formulae and procedures that are commonly practiced in their schoolwork. In this way, this process involves students in higher-order tasks of examining complex situations, forming hypotheses, and justifying answers with logical reasoning. In this regard, Olympiads are similar to modern STEM education methods in that they stress teaching critical thinking and problem solving rather than rote learning of facts and procedures.

Another benefit of Science Olympiads is their impact on student interests. Especially among students in a competitive academic environment, Science Olympiads increase interest in the science subject and in advanced topics. Further evidence is provided by Smith et al. (2021), who find that students who attended early STEM extracurricular programs (including Olympiads) are more likely to enroll in STEM degrees in higher education, and interpret these results as suggesting that early STEM engagement may affect students' degree and interest choices as well.

Science Olympiads also offer a non-school learning experience. Whereas education in school settings typically takes the form of structured lessons about the core curriculum delivered by an educator, preparation for the Science Olympiad is typically carried out through self-study, peer study, and mentorship by an experienced educator or science coach. The environment promotes self-direction and self-regulation, and enables students to interact with a peer community that shares the students' aspirations, helping to support their academic identity and their sense of belonging in the STEM fields.

The International Zhautykov Olympiad (IZhO) is one of such events. The International Zhautykov Olympiad is an international physics, mathematics and informatics Olympiad, which has been conducted since 2005, and seeks to provide high-quality problem solving opportunities to students in Science, Technology, Engineering and Mathematics (STEM) areas. The theory and practice sections thus expect participants to be able to generalize and put into practice what they have learned in a more fluid way than is usual at other olympiads. This further distinguishes IZhO from customary olympiads by being a more holistic experience.

Studies based on educational processes related to Olympiads convey the educational potential of Olympiads. In a different study, Dierks et al. (2014) examined the interests of students in science competitions and found that students participating in such competitions were characterized by investigative and analytical interests. Highly motivated students prefer problem solving with reasoning and exploration. Science competition students are more interested in science activities and are more

likely to choose science as their career than their peers who do not participate in science competitions (Höffler et al., 2019).

While the cognitive effects of participating in Olympiads are well documented, the social and psychological effects are mixed. Nevertheless, according to Höffler et al. (2017), students participating in science competitions have a higher academic self-concept than students not participating in competitions. Gender differences were also reported, as females improved their self-image less than other subjects despite achieving similar academic results, suggesting participation alone might not be enough to address these students' social-psychological processes.

Also, Nadhirah et al. (2019) suggested that the Olympiad science students may not develop their emotional and social skills even though they possess high intellectual levels as they face difficulties in controlling their emotions, conflict resolution and socialization. This suggests that Olympiads do contribute to cognitive growth, but the effects on non-cognitive skills may depend on the context and support provided during the training.

A possible negative consequence to the Science Olympiads from an education perspective is that they appear to selectively attract only a small population of high-performing students, possibly at the expense of students who would also benefit from enrichment opportunities in the sciences. Simultaneously, the competitive nature of Olympiads can cause pressure on students, and some students may even become negatively affected by the competitive nature of such events, stressing the need for carefully designing competition-based environments.

In addition to being a source of special academic enrichment, skill development, and extracurricular activity, Science Olympiads are also meaningful individual, intellectual, and career components for many students and are seen as complementary to the school curriculum. That said, the implementation of Science Olympiads has a number of challenges that must be addressed in order for Olympiads to be equitable and balanced. While a lot of research has focused on Olympiads in general, and their

impact on students' development, specific research on the IZhO and its impact on students' perceptions and experiences has yet to be conducted.

2.2 Factors Influencing Students' STEM Career Interests

The development of career interests in STEM (Science, Technology, Engineering and Mathematics) is a complex process, including many intersecting factors at the individual, social and environmental levels. Participation in Science Olympiads is one of many influential stimuli, but not the only one, in the development of students' career interests. More recent studies suggest career considerations result from the interaction of individual characteristics, educational experiences, and broad contextual influences.

At the individual level, intrinsic motivation, curiosity, and self-efficacy influence students' participation in STEM fields of study. Students with a high interest in scientific inquiry, experimentation, and problem solving tend to be more likely to pursue careers in STEM fields. According to a study by Campbell and Tirri (2017), Olympiad students have an intrinsic desire for learning and persistence and grit when they experience failure. These traits help Olympiad students succeed in science and mathematics long-term. In a study by Sahin et al. (2015), students' participation in Science Olympiads increased their self-efficacy and motivation for STEM careers. If career choice is related to self-efficacy, then experiences that contribute to the development of self-perception may in turn have long-term effects on student academic careers.

However, student characteristics are not the only contributors to career choice as social factors, such as family, also affect students' career choices. Family factors have a strong influence on students' perceptions of STEM fields, such as family structure, parental expectations, and parental education. Japashov et al. (2022) found that number of siblings, parents' educational background, and parents' involvement affected students' perceptions of potential STEM careers (Japashov et al., 2022). Family structures and social context and social influences also affect students' academic pathways. Black et al. (2005) observed that students' educational pathways

are affected by external social influences, and that career pathways are part of a wider social context that includes educational performance and other social factors.

Family influences are not the only educational influences on STEM careers. Students who attend schools with higher numbers of quality resources, experienced teachers, and extra-curricular activities are also more likely to be interested in careers in science. In formal education systems, Science Olympiads have been used as vehicles of talent development and career exploration in Singapore (Lim et al., 2014). Likewise, Balta et al. (2023b) found that students in specialized schools with additional STEM resources reported higher interest in engineering and technology as a career pathway. The findings present evidence that can support a role for positive school environments in students' motivation and aspirations.

Gender differences are one of the most studied predictors of STEM fields, and many studies have shown differences in STEM participation, performance, or self-perception between male and female students. Steegh et al. (2019) say the gender gap in science competition participation is related to social, cultural and psychological factors and find that males are more likely to enter physics and engineering fields whereas females are more likely to enter fields with higher social value.

Other reasons could include social stereotypes. Chiang et al. (2023) discuss how the cultural norms and stereotypes surrounding women in STEM can affect their confidence and willingness to engage in STEM activities. The same academic performance in a girl as in a boy does not always lead to the same perception of potential, nor the same desire to pursue competition. Science Olympiads can help to close that gap and draw attention to accomplishments customarily overlooked in girls. When female students attend inclusive spaces, they are likely to feel better about pursuing STEM careers.

Another factor influencing students' choice of career is academic performance. Those who perform well academically are generally more likely to choose a science, technology, engineering, or mathematics (STEM) career. Balta et al. (2023a); Japashov et al. (2022) also suggest academic performance might positively correlate

with interest in STEM occupations due to the theory of positive reinforcement. Students who excel academically might develop a sense of academic identity and self-efficacy in STEM fields. Olympiads can help ease this process by providing students with external recognition of their academic abilities and competencies.

In addition to individual and social influences, contextual factors, such as the economic situation, labor market, and government policies, are also relevant for the attractiveness of careers in STEM fields. According to Langdon et al. (2011), the prospect of a higher salary has drawn students to pursue STEM careers. However, according to Johnson (2012), STEM education policy has been difficult to implement largely due to the difficulties of coordination and communication between the many stakeholders in education. These findings suggest that structural factors at both the national and institutional levels may influence students' perceptions of their career prospects.

Another important factor is the opportunity to participate directly in scientific work through Science Olympiads, university research opportunities, and internships or summer research programs, to experience science in action. According to Smith et al. (2021), early exposure to STEM programs is critical, as it has an important impact on students' decisions to pursue STEM-related occupations by helping them understand the nature of STEM-related occupations and leading them to commit to a STEM career.

While much research has been conducted regarding influences on interest in a STEM career, many studies have considered the different personal, social, and environmental influences in isolation, not taking into account their interdependence. Most research uses general student samples instead of high-achieving students who take Olympiads. Therefore, the research results may not be directly applicable to competitions such as the International Zhautykov Olympiad (IZhO) where students are more motivated and have better abilities.

Little research has been done on the role of mediators, such as whether gender effects could vary depending on whether the school is single-gender or co-educational and whether this applies to participation or leadership. Availability of resources and

mentor support may mediate the relationship between academic performance and these characteristics, so understanding this interaction is essential to developing a more holistic view of the formation of STEM career aspirations.

Consequently, the current study seeks to explore these issues further by delineating the factors described above within the framework of the IZhO, namely participant sex, age at first Olympiad experience, school type, and frequency of Olympiad participation. A better understanding of these mechanisms will provide understanding into the influence of the IZhO on students' self-perception and career ambitions. This approach considers the complexity of education contexts as well as possible unexpected outcomes.

2.3 Development of 21st Century Skills through Science Olympiads

The range of competencies and knowledge that are necessary to thrive in a society undergoing rapid change and technological growth is sometimes called 21st century skills. Although there are many definitions, these skills commonly include problem solving, communication, collaboration, creativity and digital literacy. Unlike academic outcomes, which are about mastery of content, 21st century skills are about applying knowledge in unique and novel situations and about being able to deal with new and unanticipated changes and challenges. This has special importance in STEM education, where skills directly related to scientific inquiry and technological innovation are of primary importance.

Science Olympiads provide especially good practice for these skills. In a regular class, the problem types that students face usually have a fixed structure, are certain to appear, and have obvious solutions that can be derived easily. In contrast, Olympiad problems are non-routine, ill-structured, and rely on conceptual understanding and flexible thinking. The International Zhautykov Olympiad (IZhO) and other math competitions give students problems that require more than just memorization or applying learned procedures, instead requiring students to think at higher levels.

Education in problem-solving is one of the most valuable things Science Olympiads teach. Students must learn to look at an unfamiliar problem, identify the

relevant variables, and reason their way to a reasonable conclusion or solution. It also encourages logical and critical thinking skills and a flexible approach to problem-solving. In a study, Sahin et al. (2015) found participating students reported meaningful improvement in analytical thinking and problem solving skills. Likewise, in line with this, Maxutov et al. (2023) have found that participants who received physics education materials to guide their problem-solving had better performance in the complex interpretation of problems and systematic problem-solving.

In addition to developing cognitive abilities, Science Olympiads also develop communication and collaborative working abilities. Group preparation for Science Olympiads may involve discussion, or giving and receiving explanations of solutions between participants. These activities allow students to express their opinions and discuss others' viewpoints. As Stehle and Peters-Burton (2019) indicate, STEM education should promote collaborative learning environments where students engage in the communication and collaboration essential for 21st century students. Preparation for, and participation in, the Olympiad helps develop the ability to express ideas in a precise and logical manner.

Another objective of Olympiad problem-solving is to stimulate creativity and inventiveness. Olympiad problems may have more than one method to solve, in contrast to textbook problems which have one standard method. Students working on Olympiad problems are encouraged to consider alternative solutions to problems. Baran et al. (2018) believed activity- and project-based learning environments supported creativity and self-regulated learning for students, which corresponded with Olympiad problems requiring creativity and novel thinking in non-standard problems.

Self-regulation and independent learning are other examples of 21st century skills. For example, students preparing for Science Olympiads are often required to exhibit goal-setting, self-monitoring, and self-study behaviors. This also helps to develop metacognitive skills, encouraging students to reflect on their strengths and weaknesses, and alter their learning strategies accordingly. An ability to learn independently is a critical skill in modern education, as environments tend to be

constantly changing (Geisinger, 2016). For example, Olympiad participation provides for the development and practice of these competencies.

Science Olympiads also help to build students' self-efficacy in academic areas. When students are successful in a competitive setting, their belief that they can succeed academically in the future is more likely to grow. Sahin et al. (2015) highlight that students who have attended international competitions witness an increase in their confidence of ability and potential in the subject, which appears to positively influence their engagement and motivation to learn. Olympiads seem to influence students' attitudes toward learning.

However, the development of 21st century skills through participation in Olympiads presents a series of challenges, one of which is the lack of a common framework to define and assess them in the context of Olympiads. However, as Care et al. (2018) and Chalkiadaki (2018) point out, different education systems may prioritize different skills, which may make it difficult to measure skill development, and to compare results across studies.

An additional limitation is that many studies rely on self-reported measures. Accordingly, while the students' perception of their learning experiences is relevant, it may not accurately reflect their progress in skills development. Self-confidence, peer comparison, and expectations may skew an individual's perception of their overall ability positively or negatively. The findings highlight the need to combine perception-based data with objective performance data in future research.

An additional caveat is that the benefits attributed to participation in Olympiad competitions are not evenly distributed due to previous knowledge, exposure to resource materials, and the quality of their preparation for these competitions. Supporting evidence of the effectiveness of Olympiads is that the students who benefit the most from participating are precisely those who have a formalized training and are well mentored, while the students who are not supported this way tend to benefit less.

Furthermore, while Olympiads may foster cognitive and academic skill, their influence on social and emotional skill development may not be as meaningful.

Nadhirah et al. (2019) find participating in science competitions can challenge students in managing their emotions and in dealing with peers. While Olympiads can help to some extent, students need other systems that cater to the non-cognitive aspects of personality development.

Overall, there is evidence that Science Olympiads are helpful for the development of 21st century skills of students in the context of STEM education. Students who participate in Science Olympiads have the opportunity to learn how to solve problems, work collaboratively with others, and learn independently. However, competitions and other similar experiences will only be worthwhile if they have the respective resources, preparation, and a well-structured learning environment.

The presence of 21st century skills in the present research is also relevant, as the current research seeks to study the extent to which students feel that they are developing components such as critical thinking, problem solving, communication and collaboration. In terms of participation in the IZhO, this could provide evidence in relation to the potential for participation in a highly challenging academic competition to support students' development of skills for academic and career progression.

2.4 Factors Influencing Outcomes of Olympiad Participation

While Science Olympiads are a positive experience for developing academics and helping with career goals, there are some studies that show that the effects of Science Olympiad on participants vary as a function of student and context factors, including gender, age, schooling context, and the percentage of participating students who compete in competitive events. Such factors are important for providing a thorough analysis of these students, and for understanding what actual skills participation in the Olympiad equips them with.

Gender is one of the most frequently studied aspects of the STEM education system. Many researchers have found that there are persistent differences in science engagement, performance, and self-perceptions between male and female students. Steegh et al. (2019) mention cultural, social and psychological influences explaining gender differences in science competitions, as well as male students being

overrepresented in scientific disciplines like Physics and Engineering. Self-esteem and confidence in female students are other factors which can influence student achievement.

Höffler et al. (2017) found that students participating in science competitions have a higher academic self-concept versus non-participants. Female students participating in science competitions have lower academic self-concept than male participants even if both had the same academic test results. The authors conclude that gender differences in STEM are not only dependent on ability but also influenced by self-perceptions and social scripts. Competitions, such as International Zhautykov Olympiad (IZhO), can help to create and highlight positive environments where talent, achievement and success can be cultivated and encouraged. When properly balanced, they can help to improve equity by helping to achieve equal representation and encouraging the contributions of many participants.

Another variable that could contribute to differences between perceived outcomes is the student's age. Teachers report that younger students perceive a greater improvement in their skills compared to older students because younger students are more open to new experiences and enjoy the novelty. Younger students seem to benefit more from these advanced courses, perhaps because they are being exposed to advanced content earlier in their academic careers. Older students are also less likely to believe that they are improving their academic performance.

There is little research directly related to age differences at Olympiads, but research in educational psychology has shown that younger students are more likely to be motivated and older students are more likely to be concerned with performance outcome and social comparison. However, those aspects of age differences might only be important with self-reported outcomes. Those differences between students might also be due to differences in how far students have progressed rather than difference in skill acquisition.

School type may also impact student perceptions and outcomes as there is variability in school resources, curriculum quality, extracurricular opportunities,

STEM emphasis, and the presence of structured education systems. Lim et al. (2014) suggested that structured systems of secondary and university education, along with organizational support for school science competitions like Olympiads, may positively influence student performance and motivation in these fields. Likewise, Balta et al. (2023b) found that those attending specialized schools with more wide-ranging STEM education programs were more likely to express an interest in engineering and technology.

This is because vocational schools probably spend more time on problem and technology-oriented activities that are more useful to the students' technical background. Hence, the school subject matter is more aligned with the themes and content of the Olympiad, resulting in a considerable impact on the students' experience and evaluation of the Olympiad.

Another factor of interest is the number of times students have participated in Science Olympiads, though while this increases the chances to practice and learn, it does not increase linearly. It is very common after students have been trained in this way to perceive a large impact that comes simply from seeing a new kind of problem or being in a new learning environment, but this impact may decay over time, a process sometimes referred to as the plateau effect.

The phenomenon can be explained by the theory of diminishing returns, where the marginal returns of seeing a student multiple times, over a longer time period, become smaller. Hence, the student may still be making progress, but they may not be aware of their improvement because the effects are less pronounced. This discrepancy between objective development and subjective perceptions can impact the interpretation of findings in research studies that rely on data from self-reporting.

Social factors such as cultural attitudes towards STEM education, access to resources, and availability of mentorship opportunities also influence individuals' interest in participating in STEM activities. Students' experiences are not only directly influenced by family support or encouragement (Japashov et al., 2022) but are also impacted by social attitudes towards females in STEM and the impacts of social norms

on the general perceived suitability of females for various career options outside customary or more gender-stereotyped roles (Chiang et al., 2023).

These factors do not operate in isolation; the effects of attending a public or independent school, and the amount of support offered to the student, can interact with the impact of gender, and participation may have a different effect depending on the age of the participants. The complex relationships among these variables and their moderating effects on each other serve as evidence for a multi-faceted approach to Olympiad participation outcomes.

Despite the increasing volume of research on the variables, the majority of studies either consider one variable at a time or study students from non-selective populations rather than the most elite contests like the International Junior Science Olympiad (IZhO). This means that the findings are only relevant to those competitive settings with students with potentially qualitatively different motivation or academic status.

The present study addresses these shortcomings by taking into account factors other than gender and age in the specific context of the International Young Physicists' Tournament (IZhO). In addition to gender and age, the present study considers the influences of school type and participation frequency on the development of physics skills and attitudes toward the profession. What it does is offer a window into the implications of Olympiad participation on an educational level, beyond the numbers.

2.5 International Olympiads, IZhO Context, and Research Gap

International Science Olympiads (ISOs) are internationally acclaimed academic contests that promote the pursuit of excellence in science, technology, engineering, and mathematics (STEM) education while identifying and promoting outstanding students. The International Physics Olympiad (IPhO), International Chemistry Olympiad (IChO), and International Junior Science Olympiad (IJSO) are international competitions in which top students from participating countries gather to share knowledge, learn from one another, and collaboratively solve challenging problems. As indicators of academic achievement and as highly influential educational

experiences, these competitions can impact students' development and career trajectory throughout their educational careers.

A hallmark of international Olympiads is that they focus on non-routine problem solving, where students apply their theoretical knowledge to novel situations and use knowledge from all STEM disciplines. This is aligned with the established principle of contemporary education that calls for critical thinking, flexibility and problem-solving. Lim et al. (2014) have argued that organized systems of Olympiads can play an effective role in a country's pursuit for identifying and developing talent as long as they are integrated into the education system.

The International Zhautykov Olympiad (IZhO) is an example of international regional math competition. Though it has similarities with other international olympiads, the distinction with the International Zhautykov Olympiad is that it is held regionally. While the students are mostly from Central Asia and other countries in the region, the student body is diverse and students come from all over the world, offering a variety of educational systems and cultural traditions to the institution.

Another feature of the IZhO is that it spans multiple fields of science and engineering, including physics, mathematics, and informatics, being a multidisciplinary contest and enabling students to acquire knowledge and skills from multiple STEM subjects in a single contest. For example, in physics, contestants are typically expected to solve both theoretical and experimental problems. This means that although the contestants need conceptual knowledge and technical skills, it is ideal when the problems test both theory and practice, and that makes it educational as well as competitive.

Compared to other international highly selective Olympiads, such as IPhO and the IZhO, the high acceptance rate and relative academic aptitude of the participants makes the IZhO suitable for educational research. The mixture of participants from diverse backgrounds and levels of preparation gives an opportunity to research differences in the Olympiads and their participation experience. This makes the IZhO

a good natural experiment for the cognitive and non-cognitive effects of Olympiad participation.

While it is widely accepted that the international Olympiads have this level of importance, the majority of the research on these competitions has been done in the context of their impact on students' scholastic achievement and developing talent. Campbell and Tirri (2017) argue that Olympiad participation increases gifted students' motivation, perseverance, and intellectual engagement. Smith et al. (2021) likewise found that participation in STEM Olympiads during the first years of upper secondary education considerably predicted students' educational and occupational choices. Both studies suggest that participation in Olympiads appears to have a greater influence on students' long-term educational and occupational decisions than their immediate educational experiences.

One limitation of the literature is that it focuses on the third-party evaluation of student progress or outcomes through performance data and academic outcomes, rather than focusing on how students themselves experience participation. Lack of student voice in the literature limits understandings of how and why participatory experiences impact students' knowledge, skills and aspirations. Perceptual approaches provide understanding into students' motivation, competence and self-efficacy beliefs that are important for lifelong learning and career development. This kind of research is rare in the scope of Science Olympiad.

Another limitation is that there is no existing research specifically on the IZhO. The IJSO has been studied and has provided insights into the interests and characteristics of its participants and the outcomes they achieved (Dierks et al. 2014; Höffler et al. 2019), but this information is not generalizable due to differences in the competition's structure, demographics, and region. The contestants of the IZhO may differ in their educational background, funding and level of training from those of other international contests. Further research recognizing the IZhO as an educational event is warranted.

Another limitation of previous studies is that they mostly look at separate factors such as gender differences or performance effects. Likewise to the previous sections, students' experiences can be affected by gender, age, type of school, and frequency of attending school, for example. Few studies examine the joint effects of these variables, so we don't know how the different variables work together, influencing students' perceptions, and leading to the desired outcomes.

Furthermore, most studies have been conducted with typical students, not those with very high competitiveness in Olympiad. The Olympiad population may not generalize as they are only a small fraction of the population who are intensely motivated, academically able, and engaged with STEM. Thus, it may be needed to re-assess the findings of larger educational oriented studies, and to address the need for Olympiad specific research in this area.

Thus, to clarify this research gap, the aim of the present study was to investigate the perceptions of students who participated in the International Zhautykov Olympiad with regard to their development of 21st century skills and their interest in pursuing STEM careers. The perception-based approach allowed the authors to investigate Olympiad participation by considering multiple factors. It is also necessary to consider other variables, such as the participant's gender, age, school type or the frequency with which he/she attends performances.

The study contributes to the Olympiad literature by analyzing a lesser-explored Olympiad, the IZhO, in terms of its unique educational setting. Such understanding is particularly important in regions where the IZhO plays an essential role in STEM education and eases the identification of talented individuals in science and mathematics.

Ultimately, while international Science Olympiads have been internationally recognized as an efficient educational approach, there is a gap in research exploring whether such events could have a unique positive impact on students' development in a wider context. The present research seeks to fill that gap by focusing not only on the IZhO, but also on student perceptions and other implicated factors. The current study

contributes to the literature by examining the relationship between participation in academic competitions and competency development and interest in pursuing a STEM-related career, thereby providing perception into the advancement of STEM education.

2.6 Educational Value of Olympiad Participation and Implications for STEM Education

Given their growing popularity and impact, it is important to study how Science Olympiads predict other educational constructs and the ideal educational context for STEM programs. In previous sections, we have specifically focused on self-reported outcomes such as knowledge gain, skill development, and career choice. However, it is important to study the impact of Olympiad participation on such teaching behaviors, curriculum, and educational policy.

Science Olympiads help in integrating knowledge with application while conventional education focuses on having students learn knowledge within the confines of subject matter boundaries. In Olympiad problems, students integrate concepts from different subjects into one problem and apply the concepts in new environments. This improves understanding of scientific concepts and promotes a holistic view of knowledge instead of a single-discipline view. An Olympiad class enables students to refine their knowledge and develop a more flexible and integrated view of STEM topics.

Furthermore, Olympiads have been shown to encourage the practice of active learning, where students do not passively learn material but think through problems, conduct experiments, and reflect upon what they have observed. Passive learning, where learners are passive observers and are taught by teachers, may also be contrasted with active learning. Parents want their children to be active learners, as it has been shown to improve memory, motivation, and performance. The Olympiad preparation structure is thus not far removed from modern student-centered learning principles.

A second major finding of the Olympiad is the effect on the identity of students as science learners, since students who participate at a high level come to see

themselves as scientists. This identity is important during adolescence, when students may be in the midst of setting their academic and career goals. Success in Olympiad contexts may help students have confidence to pursue additional STEM education. Among students who do not achieve top results, participation can lead to a sense of belonging within the academic community.

Science Olympiads offer opportunities that foster mentorship and collaboration, important best practices of learning communities. Science Olympiad students spend time with their team mates, coaches, and teachers to prepare for upcoming competitions and further each other's knowledge and skills. Such activities foster not just knowledge and skills, but also social and communicative abilities, as Olympiad participation is seen as not only individual efforts but a collective engagement with learning processes.

From a teaching perspective, the problem-writing strategies used in Olympiad problems are also appropriate for other instructional contexts. They can provide teachers with ideas for non-routine problems and open-ended problems to use in their classes to encourage students' critical thinking skills. It is also similar to inquiry-based learning (especially discovery learning) and could improve it, since part of an inquiry-based learning program could involve some Olympiad-style learning.

However, it is worth noting that not all students have the opportunity to participate in these programs, as Olympiad activities often require resources, specialized training, and institutional support that may not be uniformly available in all educational contexts. This raises questions about the fairness of STEM education and how to reach a broader range of students. Possible interventions could include giving additional support to underrepresented groups or expanding the number of training programs to provide more opportunities to students.

Educational policy plays a large part in Olympiad participation as policymakers can embed competition-based learning into national educational systems to encourage participation. Lim et al. (2014) showed how policymakers can contribute to national talent development by providing formal support for Science Olympiads through

investment in teacher education and professional development, equity in resource allocation, provision of supportive systems for students, and promoting Olympiad participation.

The Olympiad can also be seen as an educational tool to stimulate creativity, problem solving and interdisciplinary approaches which are all core skills for success in modern science and technology. If the topics encountered are also introduced into the standard school curriculum, education is given that focuses on such situations students may face in the future. As such, Olympiads are perceived as having benefits beyond the participants.

Some critics, however, argue that competition-based learning could place too much pressure upon students by stressing grades, or more generally high performance and ranking, and subsequently reduce intrinsic motivation through extrinsic rewards. In addition, there is little evidence that the Olympiads suit all students, in particular, students who may prefer to learn in cooperative as well as discovery environments. The effects of this also have to be taken into account.

Ultimately, Science Olympiads have the potential to be a successful educational tool to improve the teaching of science through active learning and to foster students' academic identity, but may not be as effective without equitable access, supportive environments, or integration of their goals with general educational systems. The skills and concepts developed through Olympiad participation have ramifications for the future of STEM education and merit further inquiry into their long-term impacts and potential applications.

3. Research Design and Methodology

3.1 Research Design

The methodology used in this research was a quantitative research design, which was chosen as the most suitable approach to answer the research questions related to the impact of participation in the IZhO on students' perceptions of 21st-century skill development and interest in STEM careers. This approach enabled the researchers to collect and analyze numerical data and examine relationships between variables using statistical methods. This is done in order to determine the patterns, between-group differences, and associations that are the main research interest.

This study is cross-sectional because it surveys students at a single point in time. This is the appropriate design for investigating student perceptions and experiences. There will be no manipulation of variables. The methods allow group comparisons, for example, differential participation according to participant sex, subject specialization and/or type of school, and examination of relationships such as age, frequency of participation and perceived skill development.

This study is not an experiment and does not seek to explain causal relationships, but rather to identify common associations and patterns of interest within the population, which is a common and widely accepted practice in educational research that uses perception-based data to explore student views.

The selection of the quantitative survey design can also be justified based on methodological literature. Creswell states that quantitative research is used to measure and statistically analyze the data and to objectively interpret the findings. The method used is appropriate since we are interested in examining thousands of Olympiad participant responses and extrapolating trends from them in this study.

3.2 Research Questions

The study is guided by the following research questions:

1. Are there differences in the perception of skill development among male and female students who participate in the IZhO?

2. Do students specializing in different STEM subjects (Mathematics, Physics, Informatics) perceive varying levels of improvement in 21st-century skills due to their participation in the IZhO?
3. What is the relationship between students' age and their perceptions of how IZhO participation influences their development of 21st-century skills and STEM career aspirations?
4. Which type of school (public, private, vocational) reports the highest perceived benefit from participating in the IZhO in terms of skill development and career orientation?
5. What is the relationship between the number of Olympiad participations and students' perceived development of skills and STEM career aspirations?

These research questions are aligned with the study's objective of examining how participation in a high-level academic competition contributes to students' perceived development and future academic and career intentions.

3.3 Participants

The sample consisted of 103 high school participants who previously participated in the International Zhaitykov Olympiad, thereby representing high-achieving students who are interested in a career science, technology, engineering, or math (STEM) profession.

The gender distribution of the participants is as follows:

87 male students

16 female students

This asymmetry is similar to the gender ratios in international science Olympiads where boys also vastly outnumber girls, limiting the extendability of gender comparisons to these events; however, this inequality arguably gives a realistic ratio of Olympiad participants.

Participants were also categorized according to the following criteria:

Age

Subject specialization (Mathematics, Physics, Informatics)

Public, private, vocational school.

Number of Olympiad participations

A convenience sampling method was used because it targets a population that is easy to access and easily obtainable to respond to the anonymous online questionnaire. This method is easier and faster to conduct but may present a sampling bias and result in a lack of generalizability to the population at large.

Despite these limitations, this sample is relevant because it is composed of students who are all at a very high level of academic competition in relation to this study.

3.4 Instrumentation

The data were collected through an online-administered structured questionnaire. The questionnaire used in this study was adapted from Sahin, Gulacar, and Stuessy's (2015) questionnaire about students' perceptions of their participation in the science Olympiad, their career choices, and their development of various abilities and skills through the science Olympiad participation.

The questionnaire was divided into several sections:

3.4.1 Demographic Information

This section included items related to:

age

gender

school type

academic background

3.4.2 Olympiad Participation Experience

Participants were asked about:

the grade level at which they first participated

the number of times they participated in Olympiads

Such variables were used to analyze the role of experience in the outcomes.

3.4.3 Perceived Skill Development

The impact of the participation at the IZhO was evaluated along a Likert scale, where participants were asked to what extent their participation contributed to developing the following 21st-century skills:

- critical thinking
- problem-solving
- creativity
- collaboration
- scientific thinking
- communication and presentation skills
- technological literacy
- life and career skills

Responses were given on a five-point scale:

1. Not at all
2. Slightly
3. Moderately
4. Significantly
5. Extremely

3.4.4 Evaluation of Olympiad Experience

Participants evaluated aspects of the Olympiad, including:

- quality of tasks
- difficulty level
- organization
- communication
- accommodation and environment

3.4.5 Open-Ended Questions

In addition to closed-ended items, open-ended questions were administered in which participants responded to the following statements in their own words:

benefits of participation
motivation for joining Olympiads
overall experience

3.5 Data Collection Procedure

Responses to this study were collected using an online questionnaire, the link to which was disseminated to students who had previously participated in the International Zhautykov Olympiad.

As participation was voluntary, respondents were informed of the purpose of the research before completing the questionnaire. Ethical considerations were taken into account by:

anonymity (no identifying personal data collected)
confidentiality of responses
received informed consent before participating

Participants undertook the survey at their own pace, with responses being automatically collated for analysis.

3.6 Data Analysis

Statistical analyses were performed to test the relationships between these variables and group differences.

Descriptive statistics for this dataset were performed using:

means
standard deviations
frequencies
percentages

These measures provide understanding into the responses, as well as their trends.

To answer the research questions, the following statistical methods were used:

Independent Samples t-test

It has been used to examine differences between groups (e.g., differences between genders in perceived skills).

One-Way ANOVA

It is, for example, used to analyze differences between groups based on subject specialization, type of school, or frequency of participation.

Correlation Analysis

Examine the relations between continuous variables (e.g. age, skill development, career aspirations).

Statistical importance was set at the 0.05 level.

$$p < 0.05$$

This means that results are said to be statistically important if the probability of them occurring by chance is less than 5%.

3.7 Reliability and Validity

The questionnaire was modified from an already established questionnaire, thus establishing its content validity. The study employed some modifications to this questionnaire so that it can be adapted to the context of the International Zhautykov Olympiad.

The internal consistency of the Likert scale items was measured in the analysis. The presence of a set format in the questionnaires, as well as a set response scale, creates reliability and consistency in the data.

3.8 Limitations of the Methodology

However, several caveats must be noted:

Nonetheless, self-report data may be subject to bias and response distortion.

Given the sample's gender imbalance, comparisons between genders should be interpreted with caution.

Convenience sampling limits the generalizability of findings.

Due to the cross-sectional design, definitive causal conclusions cannot be drawn.

Despite these limitations, the approach is suitable to explore students' perceptions and find multiple levels of meaning in their data.

4 Analysis and Results

As part of the pre-analytical procedure to these inferential statistical analyzes, skewness and kurtosis indicators were calculated to evaluate the distribution of the data. This step was necessary because parametric inferential tests (independent samples t-test and one-way analysis of variance) are based on the assumption that the data at hand follow a normal distribution.

As shown in Table 4.1, the skewness and kurtosis measure for the variables were between -0.560 to 0.327 and -1.14 to -0.280 respectively, which fall into the range of -1 to +1, indicating that the distribution of the variables is fairly symmetric and is close to a normal distribution.

This outcome confirms that the dataset is normally distributed and that the fundamental assumptions for parametric tests are met, thus justifying using t-tests and ANOVA for subsequent analyzes. Confirming normality at this stage increases the validity of the findings and makes the interpretations when using inferential statistics more reliable.

Table 4.1. *Descriptive statistics*

	Skewness	Std. error skewness	Kurtosis	Std. error kurtosis
General skills	-0.247	0.238	-0.280	0.472
Presentation	-0.210	0.238	-0.789	0.472
Scientific Thinking	-0.210	0.238	-0.789	0.472
Collaboration	-0.0052	0.238	-1.01	0.472
Problem Solving	-0.560	0.238	-0.604	0.472
Innovation	0.305	0.238	-0.822	0.472
Creativity	-0.0467	0.238	-1.09	0.472
Technology	0.327	0.238	-1.14	0.472
Critical Thinking	-0.450	0.238	-0.844	0.472
Life and Career	-0.122	0.238	-1.14	0.472

An independent sample t-test was used to answer the first research question in terms of the effect of gender on each skill.

There were statistically important differences in three areas of skills, as shown in the following 4.2 table:

Presentation skills ($p = 0.005$)

Scientific thinking ($p = 0.005$)

Collaboration ($p = 0.021$)

These findings also lend support to the notion that gender has a meaningful influence on students' perceptions of their skill development in specific domains.

However, there were no meaningful differences in other skills, such as general skills, problem solving, innovation, creativity, technology, critical thinking, and life and career skills ($p > 0.05$) which indicates that differences between male and female students in terms of the effect of the IZhO on these skills may be very rare.

This suggests that females are perceiving greater change in these areas than males. This does not therefore necessarily mean females are better, rather it provides evidence of an important difference in self-appraisal which is an important contributor toward motivation, confidence and future participation in STEM affected by STEM interventions.

Overall, these findings provide only partial support for the first research question, as while there are gender differences, these tend to be domain specific rather than general.

Table 4.2. Independent Samples T-Test

		Statistic	df	p
General skills	Student's t	-1.88	101	0.062
Presentation	Student's t	-2.88 ^a	101	0.005
Scientific Thinking	Student's t	-2.88 ^a	101	0.005
Collaboration	Student's t	-2.35 ^a	101	0.021
Problem Solving	Student's t	-1.70 ^a	101	0.092
Innovation	Student's t	-1.69	101	0.095
Creativity	Student's t	-1.22 ^a	101	0.226
Technology	Student's t	-1.27 ^a	101	0.208
Critical Thinking	Student's t	-1.49 ^a	101	0.139
Life and Career	Student's t	-1.31	101	0.195

Table 4.3 shows descriptive statistics for the performance of male and female students in the three domains (presentation, scientific thinking, and collaboration) in which there were statistically important differences, as previously indicated.

The study shows that females scored higher on all three skills during the survey. The mean score for presentation and scientific thinking was 3.81 for females and 2.93

for males. The same pattern is found for students' skills in teamwork, with a mean of 3.56 for female students, and 2.75 for male students.

Complementing the analysis of the means, standard deviations for the answers were on average lower for female than male students. This means that, for female students, there is less variation in their experience of the situation, and vice versa for male students.

Altogether, these findings are consistent with the independent samples t-test results and suggest that in the participants' views, female participants' experience in the International Zhautykov Olympiad contributed more to the development of their communication and interpersonal skills than their male counterparts.

It is worth noting that they are based on perceived, rather than actual, attainment. Nevertheless, differences are likely to be due to self-perception shaping student confidence in their academic ability and study engagement, which in turn are likely to have considerable implications for participation and motivation and career trajectory within STEM.

Table 4.3. Group Descriptives

	Group	N	Mean	Median	SD	SE
Presentation	M	87	2.93	3.00	1.199	0.129
	F	16	3.81	4.00	0.544	0.136
Scientific Thinking	M	87	2.93	3.00	1.199	0.129
	F	16	3.81	4.00	0.544	0.136
Collaboration	M	87	2.75	3.00	1.340	0.144
	F	16	3.56	3.50	0.814	0.203

To answer the third research question: whether university students of mathematics, physics, and informatics believe they improve in 21st century skills in different proportion levels, a one-way analysis of variance (Welch's test) was adopted. The one-way analysis of variance is used as a statistical method for the simultaneous comparison of the mean scores of the different groups, allowing for different variances.

As can be seen from Table 4.4, there is no statistically meaningful difference between groups in the perception of the impact of the International Zhautykov Olympiad on the development of different types of skills ($p > 0.05$). Students with different subject specialization have almost the same opinion on the development of skills.

However, despite small differences in F-values across these skill areas, none were statistically important, suggesting that the differences between groups may be attributable to random variation rather than the academic specialization of the most skilled participants within each of the three skill areas.

From an educational standpoint, participation in IZhO leads to transferable skills that can be used outside the scope of the competition. Critical thinking, problem solving and analytical reasoning in particular seem to be developed in a generic way by engaging in difficult Olympiad tasks.

Additionally, the similarities in Mathematics, Physics and Informatics may indicate that the task structure and nature of Olympiad problems result in a similar learning experience, whether students major in Mathematics, Physics or Informatics.

Overall, the results answer the research question as it appears that participants' area of expertise and level of specialization did not affect the improvements they perceived they had made in their own skills.

Table 4.4. One-Way ANOVA (Welch's)

	F	df1	df2	p
General skills	0.2411	2	63.1	0.787
Presentation	1.8370	2	62.9	0.168
Scientific Thinking	1.8370	2	62.9	0.168
Collaboration	1.4480	2	62.6	0.243
Problem Solving	1.5175	2	62.4	0.227
Innovation	0.1054	2	61.7	0.900
Creativity	0.7932	2	60.6	0.457
Technology	0.5027	2	59.9	0.607
Critical Thinking	0.3246	2	61.3	0.724
Life and Career	0.0447	2	61.8	0.956

To examine whether age had an effect on students' views on skill acquisition, a one-way ANOVA (Welch's test) was conducted between the age groups.

In summary, as shown in Table 4.5, there was a statistically important main effect of age groups on general skills ($p = 0.010$), presentation skills ($p = 0.002$), scientific thinking skills ($p = 0.002$) and problem-solving skills ($p = 0.006$) which indicated that age played a role in the differences to which the students perceived themselves capable in these skills.

No statistically meaningful difference ($p > 0.05$) existed between the other five competencies in the 21st century skills set, collaboration, innovation, creativity, technology, critical thinking, life and career skills. In this context, this indicates that while some of the 21st century competencies are sensitive to age differences, others are perceived as more uniform across ages.

The differences within core cognitive and communicative skills make it clear that age is a major factor in students' performance in the Olympiad context. Higher order and active learning skills such as problem solving, scientific reasoning, and reasoning with evidence are more affected by students' level of academic development than other competencies such as declarative knowledge.

However, it has also been suggested that the results of the International Zhautykov Olympiad on students may depend on the stage of individual growth of the students and not all students in all of the age groups will notice the same benefits.

Thus, overall, the findings do answer the research question, as age clearly plays an important role in the students' perceptions of improvement in several important skill domains, while other skills remain relatively stable across age groups.

Table 4.5. One-Way ANOVA (Welch's)

	F	df1	df2	p
General skills	6.326	2	15.8	0.010
Presentation	8.543	2	24.6	0.002
Scientific Thinking/	8.543	2	24.6	0.002
Collaboration	1.183	2	13.8	0.336
Problem Solving	6.696	2	19.2	0.006

	F	df1	df2	p
General skills	6.326	2	15.8	0.010
Innovation	1.085	2	14.1	0.364
Creativity	0.658	2	14.3	0.533
Technology	1.672	2	13.8	0.224
Critical Thinking	3.052	2	18.5	0.071
Life and Career	1.402	2	16.0	0.275

Table 4.6 presents the means and standard deviations for the age categories and skill areas where differences were found using ANOVA.

Across all domains, students aged 13 to 14 years old were found to score highest in general skills, presentation, scientific thinking and problem solving. In contrast, students in the middle age group (15 to 16 years old) were consistently lower performers than the youngest age group and students in the oldest age group (17 to 18 years old) performed in between the two groups.

For example, in the case of general skills, the youngest group had a mean value of 4.00, the middle one 2.95, and the oldest group 3.41. Same distribution can be seen in the presentation, scientific thinking and problem solving skills, so this pattern is not limited to only one of the skills.

From the table above it can be deduced that younger students felt that their performance improved more than older students did over the same period of time due to participation in the International Zhautykov Olympiad, which can be explained by the novelty effect: students participating in such an Olympiad for the first time may feel greater improvement in their performance.

Another possible explanation for these age differences is the level of initial skills. As younger students begin with less confidence or ability, any improvements are likely to feel greater. Older students, who have more experience with these academic tasks, may be more likely to reflect on their own behavior and give less extreme self-assessments.

Linked to this is the issue of developmental trends in self-evaluations; as students get older, they become more skilled at accurately assessing themselves, and their self-evaluations may become more conservative.

The results from these models confirm the main result of the ANOVA analysis, but offer a more subtle understanding of the age effect. They show that the perception of the impact of Olympiad participation on skill development is not uniform across the different age groups, and is, in fact, stronger among the younger participants, who perceive more skill development.

Table 4.6 Group Descriptives

	Age	N	Mean	SD	SE
General skills	1	6	4.00	0.632	0.258
	2	38	2.95	0.957	0.155
	3	59	3.41	0.949	0.124
Presentation	1	6	3.83	0.408	0.167
	2	38	2.82	1.182	0.192
	3	59	3.15	1.172	0.153
Scientific Thinking	1	6	3.83	0.408	0.167
	2	38	2.82	1.182	0.192
	3	59	3.15	1.172	0.153
Problem Solving	1	6	4.50	0.548	0.224
	2	38	3.58	1.177	0.191
	3	59	3.54	1.179	0.154

To compare whether there were differences in perceptions of skill improvement between public, private, and vocational schools, an ANOVA test (Welch's test) was performed.

From Table 4.7 it can be inferred that there is no important difference in the mean in any of the skill areas based on the type of school, except for the technology area, where the mean in the p value (0.037) is statistically important. In all the other skill areas, p values more than 0.05 have been reported.

Furthermore, Table 3.8 presents the descriptive statistics of the technology skills. Based on the technology skills, it was found that vocational school students have the highest mean ($M = 3.00$, $SD = 1.487$) compared to public schools ($M = 2.59$, $SD = 1.359$), and private schools ($M = 2.00$, $SD = 1.069$).

This finding suggests that VET students perceive participation in the International Zhautykov Olympiad as having a stronger effect on their technology

skills. Vocational education tends to be applied education, and vocational education is often more technical and more likely to include technology-oriented topics than the general curriculum, which could explain a difference in perception. They may be better able to understand the technology of participation in the Olympiad.

However, the distribution of benefits to other skills is not considerably different between types of schools, meaning the development of general cognitive and academic skills resulting from participation in Olympiads is generally similar across schools.

In general, these findings partially answer the research question: school type has an effect on a small subset of skills, such as technology but little effect on other skills.

Table 4.7 One-Way ANOVA (Welch's)

	F	df1	df2	p
General Skills	0.146	2	43.6	0.864
Presentation	1.836	2	40.3	0.172
Scientific Thinking	1.836	2	40.3	0.172
Collaboration	0.122	2	44.6	0.886
Problem Solving	0.635	2	41.6	0.535
Innovation	1.939	2	43.2	0.156
Creativity	0.603	2	41.2	0.552
Technology	3.577	2	41.5	0.037
Critical Thinking	1.004	2	43.2	0.375
Life and Career	1.100	2	42.3	0.342

Table 4.8 shows descriptive statistics of perception of improvement in technology-related skills by type of school to further detail the difference in mean scores between groups obtained from the ANOVA analysis.

For students learning in vocational institutes, it shows that they have a higher mean score ($M = 3.00$, $SD = 1.487$) than the students learning in public schools ($M =$

2.59, SD = 1.359). Meanwhile, the lowest score is from students learning at private schools with a mean score of (M = 2.00, SD = 1.069).

The distribution of perceived technological competence improvement also provides evidence for an improvement gradient, suggesting the vocational school students improved relatively more than high school students. Likewise, because the standard deviation of perceived technological competence improvement is greater for vocational school, it may suggest that vocational school students have a wider range of improvement.

These results confirm the results of the ANOVA analysis and indicate that the type of school does matter when it comes to developing technology-related skills in the Olympiad. The reason students of vocational schools perceive a greater improvement in these skills could be related to their exposure to practical and technical work, making them more likely to benefit from the technology elements of the Olympiad.

Overall, the descriptive results provide evidence in support of the hypothesis that the effect of school type is domain-specific, as the technology skills domain was the only one that appeared to vary.

Table 4.8 Group Descriptives

	School type	N	Mean	SD	SE
Technology	Pr	22	2.00	1.069	0.228
	P	61	2.59	1.359	0.174
	V	20	3.00	1.487	0.332

To investigate how participation frequency influences perceived skill improvement, a one-way ANOVA (Welch's test) was performed across groups defined by the years of Olympiad participation.

However, as shown in Table 4.9, Participation Frequency appears to have a statistically important effect only on Critical Thinking skills ($p = 0.033$), whereas other cognitive disciplines exhibited no statistically important differences ($p > 0.05$).

This suggests that the impact of participation frequency may be selective, mainly influencing specific cognitive domains rather than showing common effects across various skill areas.

As there are no further meaningful differences between most skill types, it can be concluded that merely increasing the attendance in the activities does not lead to continuous perceived increase of development, e.g., in problem solving, creativity, or collaboration. It seems that with time the skill development reaches a plateau.

Her research also explores the question of if the effects of the test may be generalized to other cognitive skills. Critical thinking, however, had a large treatment effect and may be a particularly well-suited skill for repeated practice in a complex problem-solving environment as it involves analysis, evaluation, and reasoning.

Taken together, the results suggest that the effect of the frequency of participation is domain-specific and that only in the case of developing critical thinking there is an important impact. This provides part of the answer to the research question, that frequent participation has a positive impact on the development of some higher order thinking and cognitive skills.

Table 4.9 One-Way ANOVA (Welch's)

	F	df1	df2	p
General Skills	0.942	3	26.4	0.435
Presentation	0.275	3	25.5	0.843
Scientific Thinking	0.275	3	25.5	0.843
Collaboration	0.767	3	25.2	0.523
Problem Solving	0.679	3	25.3	0.573
Innovation	2.054	3	24.5	0.133
Creativity	2.638	3	24.7	0.072
Technology	0.926	3	25.7	0.442
Critical Thinking	3.410	3	24.4	0.033
Life and Career	0.542	3	24.7	0.658

Table 4.10 provides descriptive statistics for critical thinking by frequency of participation group in order to clarify the statistically meaningful results of the ANOVA test.

The overall rate of intervention participation found in the experimental group accounts for these differences between the groups. The means in Group 1 (1-10 participations) and Group 3 (20-30 participations) were similar. They were higher than those found in Group 2 (10-20 participations): $M=3.74$, $M=3.71$ and $M=3.46$. The mean of Group 2 is $M=2.88$. Group 4, the group with the most participations (over 30), had a mean score of 3.03.

This indicates that there is no correlation between how often students mentioned participating in these activities and their perceived gains in critical thinking skills (as demonstrated by the large range on the y-axis across the many levels of participation).

One reason for this discrepancy may be that Olympiad students have a different thought process at their disposal, so they find progress more stimulating. However, in the long term they don't feel like they're getting better at Olympiads as often, so their self-evaluations drop. As students enact these levels of participation, they may move along a continuum of improvement by developing more advanced problem-solving skills.

Another explanation focuses on a change in self-appraisal standards. With experience, students may become more critical judges of their own abilities. So they may perceive their skills as improving less than they do.

Table 4.10 *Group Descriptives*

	Number of Participation to Olympiad	N	Mean	SD	SE
Critical Thinking	4	32	3.03	1.177	0.208
	3	7	3.71	1.496	0.565
	2	25	2.88	1.424	0.285
	1	38	3.74	1.032	0.167

5 Discussion

The purpose of this paper is to examine the effect of the International Zhautykov Olympiad (IZhO) on students' self-reported views on 21st-century skill development and STEM career intent. The findings provide insights regarding the role of academic competitions on student cognitive and non-cognitive development and how this can play out in the 21st century. However, the results also show that the effects are conditioned on individual-level and context-level factors, such as gender, age, educational level, and frequency of participation.

In summary, and in line with wider research on Olympiad training environments, students attending IZhO have an increase in self-perceived cognitive development across all nine cognitive skills tested in the current study (problem solving, self-regulated learning, scientific thinking, critical, creative and independent thinking) which involve dealing with open-ended, complex, non-routine problems. This is a more demanding task than working through the standard curriculum in the classroom, which normally includes a high degree of knowledge recall.

5.1 Gender Differences in Skill Development

Important differences for genders were identified in presentation, scientific thinking, and collaboration. Female students perceived a greater improvement than male students. Overall, Olympiad participation is a potential way to support development of communication and interaction-based competencies among female students.

Another point to consider is that Olympiad-style environments are ones of discourse, discussion, and group problem solving, which may assist with the development of self-efficacy and perception. Additionally, females typically have less opportunity to participate in competitive academic STEM environments, and competitions like the IZhO may create a sense of confidence.

However, it should be noted these are self-reported measures. The greater confidence in females could potentially be due to differences in self-awareness,

motivation or interest rather than objectively greater English ability. That said, self-perception is a large factor influencing confidence, participation and choice of future academic pathways.

Disparities in self-efficacy in STEM, however, are sometimes attributable to sociocultural and educational factors that exert pressure on students and affect their interest, confidence, and feeling of competence differently for females and males in some contexts. The supportive and intellectually stimulating environment of Olympiad settings may help reduce such barriers and provide an opportunity for females to show their abilities and engage in constructive collaborative learning experiences. This highlights the importance of creating inclusive academic environments that promote equal participation and support diverse learners across various educational contexts.

Furthermore, these statistically important differences are not seen across the other skill domains, indicating that the effects of Olympiad participation on students are not strongly related to student gender, and other skills that may be affected by gendered aspects are available to all the students who participated.

5.2 Differences Across STEM Specializations

Neither the participants specializing in Mathematics, nor those specializing in Physics, nor Informatics produced statistically meaningful differences, meaning that the students seem to experience the IZhO through the lens of their specific specialization.

This may be seen as a sign that the skills learned in Olympiad contests are transferrable across disciplines. The IZhO may promote the development of transferrable cognitive skills such as analytical reasoning, problem solving, and critical thinking, which are important in a number of different fields of science, technology, engineering, and mathematics (STEM).

The lack of these effects for Olympiad problems in specializations other than the one they pertain to suggests that Olympiad problems equally likely constitute more of a cognitive training environment for all students, independent of their specializations, and less likely act as a test of pre-existing specialized knowledge.

A further implication of this result is that the interdisciplinary structure of the Olympiad problem may be a property of the problem itself, as many problem-solving tasks in the Olympiad require students to draw on knowledge and skills from more than one subject. This may explain the observed uniformity of development. Such a broad approach also follows the trends of modern education that tend to value cross-disciplinary competencies and the ability to flexibly apply knowledge in various contexts.

5.3 Age-Related Differences

An important finding of this study was the effect of age, whereby across all domains of perceived skill improvement (general skills, presentation domain, scientific thinking and problem solving domain), younger students (13 or 14 years) reported greater perceived skill improvement than older students.

This suggests there may be a greater perceived positive effect of Olympiads on younger students. A proposed explanation of this effect is the novelty of first exposure to high-level academic competition and the perceived learning or growth from it. For the younger ones, the experience of solving challenging problems and competing with others at an international level can be a radically different experience to that in school.

Alternatively, earlier schooling may begin at a lower baseline level of skills and therefore, younger students notice more gains simply because there is more room for noticeable improvement. Conversely, older students may already possess a high level of skills and therefore, notice smaller gains.

Older students might engage in more critical self-assessment, which would lead to a more cautious self-evaluation of their progress. This might be consistent with the general trend for age and experience leading to more realistic self-assessment.

Therefore, some of the variations by age group might be due to the different expectations participants have in regards to learning. Younger students might start with a more open and curious mindset when they start an Olympiad problem set, and thus might perceive themselves to be making larger gains in learning. Older children, who are probably preparing for a transition to secondary school or from secondary school

to university might be more concerned about progress in terms of results, and less accepting of progress independent of skill.

Furthermore, exposure to advanced coursework may serve as an early indicator of a student's interest and persistence in pursuing STEM fields in the long run. Exposure to academically challenging experiences at a young age may help to foster students' self-confidence and interest levels in science, technology, engineering, and mathematics. This stresses the importance of recognizing and nurturing talented students at earlier stages of their education.

In general, these findings indicate that developmental considerations need to be factored in when considering the efficacy of educational interventions, such as Olympiad participation, which may be more or less effective depending on the stage of academic/cognitive development.

5.4 Differences Across School Types

With respect to influences of the type of school on perceived level of developed skills, statistically meaningful differences were only found for technology skills. More skills were perceived to be developed for students from vocational schools when compared to students from public and private schools. For other skills, there were no statistically meaningful differences.

It may be because vocational education is more applied and practical than other forms of education, including more technical or hands-on activities, and learners in such programs may therefore be more able to recognize and take advantage of technology-enabled or technological aspects of Olympiad participation.

It is possible that differences by school type reflect differences in resource availability, pedagogical approaches, or learning environments. For example, it is possible that vocational schools are simply better at applied and technical skills than other school types, which may be more relevant to participation in an Olympiad. This alignment may help students learn to make inferences and use these experiences effectively. However, as the school type variable did not have much impact on most

skills, the participation in Olympiad events may be one way to level the playing field, allowing students to gain similar experiences regardless of educational type.

However, the lack of similar differences for other academic skills suggests that the overall effects of participation in the IZhO are largely the same for other types of schools and that Olympiad participation tends to have similar effects on the general development of several other academic skills across different school types.

5.5 Participation Frequency and Skill Development

One of the study's more conceptually important findings related participation with perceived skill development. In this case, only the skill of critical thinking (not critical skill development) had a statistically meaningful difference between participation groups. No differences for the other skills were found to be statistically important.

More importantly, the descriptive analysis shows that the relationship is not linear as students who showed lower and higher levels of participation reported higher levels of perceived improvement, while students who showed moderate levels of participation reported lower levels of perceived improvement.

This non-linear pattern implies a more complex relationship between participation and learning, with a stage-like process of rapid learning, plateauing, and renewed learning when users reach a new threshold of participation.

Thus, another implication of these results is that an optimal structuring of Olympiad preparation activities is a non-linear problem and that constantly easing learning may reduce the perceived usefulness of participation. Consequently, for students to remain interested, and to encourage further skill acquisition, they should be exposed to increasingly complex and varied problem solving situations.

The results of this study also indicate the importance of processes to reflect on existing knowledge. Repeating the experience of Olympiad tasks allows students to better understand their own strengths and weaknesses, which then influences their self-assessment processes. Thus, reflection and feedback may play an important role in the actual and perceived competence development in preparation courses.

This may be because initial training introduces students to the new problem-solving model, leading to a large perceived improvement, whereas the effect wears off as students become more familiar with solving problems through this approach as they gain more experience. At high levels, students may experience gains when participating in complex tasks that require greater levels of engagement.

Another possibility is that students become more able to evaluate themselves as they gain experience, leading them to set higher standards for their own performance and perceive less improvement.

The results suggest that the relationship between participation and learning is more complex than initially thought. Repeatedly participating in the social context may not be more effective, but the nature of the participation and its intensity are the determining factors.

6 Conclusion

The purpose of this thesis was to study the relationship between participation in the International Zhautykov Olympiad (IZhO) and high school students' perceptions of their development of 21st century skills and their intention to study or work in the field of science, technology, engineering and mathematics. This research premise was based on developing more advanced thinking skills and preparing students for the complexities of modern science and technology.

Given the results of this paper, we can conclude that the participation in prestigious academic competitions is linked to a positive impact on students, both in cognitive skills and in non-cognitive skills. In the domain of non-cognitive skills, students reported an increase in critical/analytical thinking, problem solving, scientific reasoning, communicating and collaborating skills. The findings here confirm that the Olympiad-based learning environment offers students opportunities to engage in more in-depth, analytical and creative approaches to learning than is typically provided in a regular classroom setting.

The present study makes an important contribution as the results show that the effect of participation is not uniform and is moderated by a number of student and contextual factors which shape perceptions of skill development. A similar pattern of results for female students occurred in regard to perceived improvement in presentation skills, scientific thinking, and group work skills. This suggests that participation-supportive environments can build self-efficacy in diverse group members.

Another interesting result was that with respect to nearly all the key skill areas mentioned above, younger students reported that they were improving more so than older students, suggesting that providing these students with more rigorous academic experiences earlier in their education may have more impact on how students perceive their learning experiences (and themselves). Developmental factors also impact how students view their own progress, with older students often being more self-critical than younger ones.

As no important differences between STEM fields were found, the gains in the STEM fields are not driven by the participants' preference for a particular STEM field. The results suggest interdisciplinary skills fostered by Olympiad participation are easily transferable across a variety of scientific disciplines. The skills gained from the Olympiads are not limited to a single STEM field.

To analyze the impact of school type further, the predictors show that school type only has a small impact on students' perceived skill improvement. It is only in technical skills, however, where vocational school students experience a greater increase in skills. This points to the relationship between theoretical and practical learning environments, as well as the impact of prior education on Olympiad participation.

The most important finding of this study, however, is that the relationship between participation frequency and perceived skill improvement is not linear, as more frequent participation in activities did not lead to greater perceived improvement in skills or abilities. Conversely, the findings suggest that students do not show linear growth, but rather undergo phases of development, plateauing, and reflection, which underscores the importance of examining not only the intensity, but also the depth of academic competition engagement.

The results support the view that Olympiads such as the IZhO serve not only to select the most talented, but are also very effective as an educational tool, producing motivated and engaged learners, improving academic self-concept, and raising awareness about future STEM study and career opportunities. The findings are relevant for worldwide efforts to develop STEM education and prepare students to meet challenges posed by rapidly advancing science and technology.

From a practical standpoint, the results from this sample suggest that teachers might wish to include elements of Olympiad-style instruction, such as complex and non-routine problems, independent problem solving, and collaborative problem solving in their classrooms to some extent. Further, the results of this study suggest that teachers should consider students' age, background and experience when including

such elements, as it might help them to provide more appropriate and effective supports for different groups of students. Third, non-linear progressions suggest that challenge and novelty need to be maintained in order to keep learners engaged and to maximize the potential for learning.

Despite the above contributions, one of the limitations of this study is that data were self-reported by study participants, making it subjective in nature. Although perceptions were useful indicators of motivation and confidence, they are subjective, and the cross-sectional design did not allow researchers to investigate long-term effects of participation in the program. Use of a sample population made up entirely of Olympiad participants may also limit the generalizability of results.

Future work could build on these initial findings by utilizing longitudinal designs looking at changes over time and additionally by using more objective measures of performance rather than solely relying on self-report measures. Future work could also seek to include students from different educational systems in order to further develop our understanding of the impact of participation in Olympiad competitions. Future research needs to examine the mechanisms behind non-linear development trajectories, and how educational benefits of repeated participation can be most effectively realized.

In summary, this dissertation presents a picture of the International Zhautykov Olympiad as a complex, multidimensional educational experience. The Olympiad not only develops a range of skills, but also affects the academic identity of students, and shaping their future study and career path. These findings support the need for academic competitions to be included in the modern educational framework, and included as an educational tool to help inspire talent, innovation and the next generation of STEM specialists.

6.1 Limitations

Although it does provide several important insights into how participation in the International Zhautykov Olympiad influences students' perceived skills and STEM career aspirations, the present research has limitations that should be acknowledged.

First, the study used self-reported measures that may not be indicative of actual student skills. While self-reported data reflect student motivation, self-efficacy, and engagement, they do not necessarily correlate with skill formation and retention. However, self-bias, social-desirability and self-perception differences may produce a tendency to over- or underestimate oneself especially when self-reporting.

Second, as this research is based on a cross-sectional design, data was collected at one point in time, making it impossible to assess the longitudinal influence of participation. This would also allow us to understand how students have developed their skills and what their perceptions of participation were in the long run.

Another weakness of the sample selection is that the sample consisted of students who participated in the International Zhautykov Olympiad, which is a prestigious and academically gifted group of students. Thus, the study's sample might not be representative of the population of students, and the sample's bias toward males might impact the interpretation of the findings related to gender differences.

Another limitation could be due to the use of a convenience sample, as participants were not randomly chosen, but selected based on their availability and willingness to respond, potentially limiting the representativeness of the sample and generalizability of the findings.

There are limitations regarding the construct validity of the scope of measurement, as not all 21st-century competencies were covered in the questionnaire. Some of the 21st-century competencies such as creativity, collaboration, and solving real-world problems are not completely captured in the questionnaire. Differences in cultural and educational background among participants may also affect their comprehension of survey questions.

Statistical tests, such as t-tests and ANOVA, have been performed to determine whether there is a difference in the mean scores, however, not all of the possible confounding variables have been controlled for. Confounding variables that might affect the scores include level of previous achievement, quality of preparation, socio-economic status, and similar factors.

Nevertheless, this contribution to understanding Olympiad participation in student development remains valuable. In future research, these limitations may be addressed, providing additional insights into how academic competitions including Olympiads affect students' academic outcomes and career paths.

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Appendices

Appendix A

1. Which subject did you participate in?

Mathematics

Physics

Informatics

2. Gender

Male

Female

3. Age

11 12

13 14

15 17

18 Other

4. School Type

Public Private

Vocational / Professional

Other

5. How was the selection process for the team to participate in IZHO?

Selection was only at school.

There were several stages of selection.

6. What type of benefits do you think you will get or have already gained from participating in IZHO?

7. Write your major that you possibly want to study in college/university.

Example: Mechanical Engineering.

8. Write 3 factors, in order, that most affected your interest in Olympiads.

Example: Math teacher.

9. Are any of your parents, siblings, aunts, or uncles

Mathematics/Physics/Informatics professionals?

Yes

No

10. If yes in question 9, please indicate their relationship to you.

Example: parent, uncle, sibling.

11. How much do you believe that participation in IZHO influenced your career interest?

No influence

Reinforced my decision

Changed my decision

Made me confused

12. Why do you think so in the previous question?

13. In which grade did you first participate in Olympiads?

Kindergarten

1st grade 2nd grade

3rd grade 4th grade

5th grade 6th grade

7th grade 8th grade

9th grade 10th grade

11th grade 12th grade

14. How many times did you participate in Olympiads?

Please write the number below.

15. How much do you believe that participation in IZHO contributed to improving the following skills?

Scale:

Not at all Little

Somewhat A lot

Extremely

Skills:

Presentation Scientific Thinking

Collaboration Problem Solving

Innovation Creativity

Technology Critical Thinking

Life and Career

16. Please rate each of the following aspects of the International Zhautykov Olympiad using a scale from 1 to 5.

1 = unsatisfactory

5 = completely satisfactory

Aspects:

Quality of problems at the Olympiad

Difficulty of the tasks

Originality of the problems

Appeal process

City Tour

Quality of the food provided

Accommodation: convenience, cleanliness, service

Communication with the organizers of the Olympiad

Opening Ceremony of the 20th International Zhautykov Olympiad

Friendship Evening

Trip to Medeu Skating Rink

Fizmat Education Fair 2024

17. Please give us your feedback.

18. Your wishes?