New trends in research skills development of future teachers: quantitative approach and empirical studies

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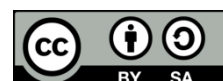[3]Department of Informatics, M. Auezov South-Kazakhstan State University, Shymkent, Republic of Kazakhstan

Article Info	ABSTRACT
	The purpose of this study was to investigate the relationship between the use of technology and the development of research skills in future teachers, specifically current graduate students participating in Mathematical Olympiads. The study used a quantitative approach and analyzed data collected through a survey. The findings indicated that quantitative analysis skills, problem-solving skills, communication skills, and research methodology skills are the dimensions of research skills in future teachers. The results showed that the use of digital tools for literature searching and curation, online courses and workshops (OCWs), collaborative learning and discussion forums, and data analysis software significantly and positively affected research skills. However, the study failed to provide evidence that digital portfolios (DPs) affected research skills. The limitations of the study and recommendations for future research are discussed. In conclusion, the findings highlight the importance of technology in the development of research skills in future teachers and suggest that technology-based learning resources and tools should be integrated into teacher training programs.

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1. INTRODUCTION

Teachers need research skills for continuous professional development. As the field of education evolves, future teachers must be able to grow and develop their skills, knowledge, and expertise in order to remain current and effective in their practices. Research skills provide a foundation for this ongoing growth and development. Research skills empower teachers to access and analyze data, information, and evidence to inform their teaching practices and make informed decisions about their instruction [1]. Evidence-based practice is critical for ensuring that teaching is effective and responsive to the needs of students [2]. Improved teaching outcomes are a challenge that teachers, researchers, and related decision-makers strive to overcome. Therefore, empowering teachers with competencies to improve their teaching outcomes is essential. Teachers who possess strong research skills are better equipped to design and implement effective instructional strategies, which can lead to improved student achievement [1]. This is particularly important in a rapidly changing educational landscape where new technologies and innovative approaches are constantly emerging. In addition, research skills also involve critical thinking and problem-solving, which are important skills for teachers to develop in order to effectively address the challenges and complexities of teaching. By engaging in research, teachers are able to develop their ability to analyze and solve problems, which can be applied in a range of educational

contexts [3]. Hence, it is essential for future teachers to have research skills. Teachers with strong research skills are more likely to engage in innovative and creative practices in the classroom. This can help create a dynamic and engaging learning environment for students and foster a culture of innovation and exploration in education.

The advent of new technologies has brought about undeniable changes in the field of education. In recent years, the integration of technology in the classroom has become increasingly common, offering numerous benefits for both teachers and students [4], [5]. For teachers, the use of technology offers new opportunities to enhance their teaching methods, engage students more effectively, and facilitate the learning process. With the help of digital tools, teachers can access a wealth of information, resources, and educational materials, making it easier to plan lessons, assess student progress, and create a more dynamic and interactive learning environment. Additionally, technology also provides teachers with new methods for collaboration and communication, allowing them to connect and share resources with other teachers around the world. However, the main question is the following: do technologies play a role in the development of research skills for future teachers? If so, how?

Access to information is essential for effective research, and technologies provide teachers with easy access to a wealth of information and resources. Digital tools for literature searching and curation, such as databases and search engines, allow future teachers to find and access relevant studies and articles. Online courses and workshops (OCWs) also provide opportunities for future teachers to learn about the latest research and best practices in education. Another key reason why these technologies are important for the development of research skills of future teachers is that they provide opportunities for skill development. Collaborative learning and discussion forums provide a space for future teachers to engage in discourse and to share their thoughts and ideas with others. This can help to build critical thinking and problem-solving skills, which are important for conducting effective research. Data analysis is an important aspect of research, and data analysis software, such as spreadsheets and statistical software, helps future teachers efficiently manage and analyze data. This is critical for understanding the results of studies and for making informed decisions about instruction. By incorporating these digital tools into their professional practice, future teachers can become more effective researchers and educators.

Despite the undeniable impact of technologies in education as well as their role in the development of research skills, the existing literature fails to provide programs for the development of technological tools in order to increase the research skills of teachers. Such a lack of programs for the development of technological tools to enhance the research skills of teachers may stem from the insufficient investigation of different aspects of this issue. Therefore, to bridge this theoretical gap, the current study aims to identify how existing technologies are effective in developing the research skills of future teachers. For this purpose, the existing literature was first studied and the technologies affecting the development of future teachers' research skills were identified, and then, using quantitative methodology, empirical evidence was presented for the impact of these technologies on teachers' research skills. The present study highlights the importance of technology in the development of research skills in future teachers and provides valuable insights for those working in the education sector. By presenting a comprehensive overview of the current state of technology in education and its impact on research skills, this study makes a significant contribution to the field and provides a foundation for future research in this area.

2. RESEARCH BACKGROUND
2.1. Research skills of teachers
2.1.1. Quantitative analysis skills

One of the skills teachers are required to make data-driven decisions in the classroom, design and evaluate educational programs and interventions, and critically evaluate the results of educational research is a skill that provides them with a systematic and objective way of analyzing and interpreting data and allows for evidence-based decision making. Quantitative analysis skills are an important aspect of research in education and provide a systematic and objective way of analyzing and interpreting data [6] and enable researchers, including teachers, to test hypotheses, determine relationships between variables, and make predictions about future outcomes [7]. With the ability to process and organize large amounts of data, researchers can make sense of complex information and communicate their findings in a clear and concise manner. Additionally, quantitative analysis skills also allow for the evaluation of the reliability and validity of data and research methods, ensuring that findings are accurate and trustworthy [8].

Quantitative analysis skills refer to the ability to use statistical methods and mathematical models to analyze and interpret data. The mastery of quantitative analysis skills is crucial for teachers to make data-driven decisions in the classroom, design and evaluate educational programs, and critically evaluate the results of educational research. Quantitative skills are essential in designing and evaluating educational programs and interventions as well as in interpreting the results of educational research. Therefore, the first hypothesis of this study is concluded as: quantitative analysis skills are a component of research skills of future teachers (H1).

2.1.2. Information seeking skills

Information seeking skills refer to the ability to locate, retrieve, and evaluate information effectively and efficiently [9]. In the context of education research, these skills are crucial for teachers as they enable them to gather information and data to inform their research and decision-making. One of the key benefits of strong information seeking skills is the ability to access various sources, including academic journals, books, and online databases. Teachers with such skills can find relevant and up-to-date information on their area of research as well as stay informed on the latest developments in their field. Additionally, these skills also help teachers critically evaluate the quality and reliability of the information they find, ensuring that the information they use is trustworthy and relevant.

Another important aspect of information seeking skills is the ability to synthesize and integrate information from multiple sources [10], [11], that allows teachers to build a comprehensive and well-rounded understanding of a topic and to use this knowledge to inform their research and decision-making. Information Seeking Skills are important for teachers in the context of research as they allow them to locate and evaluate information effectively, stay informed on the latest developments in their field, and use high-quality and relevant information to inform their research and decision-making. In ensuring that research is based on accurate and up-to-date information, the utilization of information seeking skills becomes crucial. Hence, the second hypothesis of this study is designed as: information seeking skills are a component of research skills of future teachers (H2).

2.1.3. Problem-solving skills

Information seeking problem-solving skills refers to the ability to identify, analyze, and solve problems effectively and efficiently [12]. In the context of education research, these skills are critical for teachers as they allow them to address the complex and diverse challenges they face in the classroom and in their research. By helping teachers break down complex problems into smaller, more manageable parts and find effective solutions to the challenges they face, problem-solving skills involve a systematic approach that includes defining the problem, gathering information, generating options, evaluating alternatives, and implementing a solution [13]. In addition, problem solving skills also involve the ability to think critically and creatively, and to consider a range of perspectives when addressing problems that enable teachers to consider a variety of solutions and to find innovative approaches to problem-solving. Another important aspect of problem-solving skills is the ability to evaluate the effectiveness of solutions and to make adjustments as needed. This helps teachers to ensure that their solutions are effective and sustainable and to make any necessary changes over time.

Problem-solving skills are important for teachers in the context of research as they allow them to address the complex and diverse challenges they face in the classroom and in their research [14]. Mastery of problem-solving skills encompasses a systematic approach that includes critical and creative thinking as well as the ability to evaluate solutions and make adjustments as needed. Such skills play a crucial role in assisting teachers in discovering effective and sustainable solutions to the challenges they encounter. Subsequently, the third hypothesis of this study is designed as: problem-solving skills are a component of research skills of future teachers (H3).

2.1.4. Communication skills

Communication skills refer to the ability to express ideas and information effectively, both verbally and in writing [15]. In the context of education research, these skills are critical for teachers as they allow them to share their research findings and ideas with others, including colleagues, students, and the wider academic community. Effective communication skills encompass various abilities, such as clear and concise expression of ideas, active listening, understanding others' perspectives, and adapting communication styles for different audiences [16]. By sharing research findings in an accessible and meaningful manner and engaging in constructive dialog with colleagues and peers, teachers facilitate effective knowledge exchange. Furthermore, strong communication skills involve presenting information and data with clarity and impact, using visual aids, charts, and graphs as necessary. This aids teachers to effectively convey their research findings and building a persuasive case for their ideas. Additionally, proficient writing skills, including the ability to produce academic papers, grant proposals, and other research-related documents [17], allow teachers to disseminate their research findings to a wider audience and make a meaningful contribution to the field of education.

In the context of research, communication skills play a vital role for teachers by enabling them to share their research findings and ideas with others, engage in constructive dialogue, deliver information and data effectively, and write clearly and persuasively [18]. By possessing these essential skills, teachers can effectively communicate their research findings and ideas, thus making a valuable contribution to the field of education. Thus, the fourth hypothesis of this study is considered as: communication skills are a component of research skills of future teachers (H4).

2.1.5. Research methodology skills

Research methodology skills encompass the knowledge and understanding of diverse research methods and techniques employed in conducting studies [19]. In the realm of education research, teachers greatly benefit from these skills as they establish the groundwork for designing and conducting high-quality studies. A solid grasp of research methodology empowers teachers to judiciously select the most suitable research method for their study, while also enabling them to design and implement their research endeavors systematically and rigorously. This meticulous approach ensures the credibility and reliability of the research findings, thereby allowing the study results to inform decision-making and advance knowledge within the field of education. Research methodology skills encompass the capacity to critically evaluate existing research studies, recognizing their limitations and strengths in terms of design and methodology [20], [21]. This understanding enables teachers to discern the limitations of prior research studies, prompting them to design their own investigations that address these limitations and drive progress within the field of education [1]. Furthermore, research methodology skills entail adeptness in analyzing and interpreting data as well as using statistical techniques to test hypotheses and derive conclusions. By wielding these skills, teachers can extract meaningful insights from their research data and effectively present their findings in a clear and concise manner.

Research methodology skills are important for teachers in the context of education research as they provide the foundation for conducting high-quality research studies, allow teachers to choose the most appropriate research method, design and implement research studies in a systematic and rigorous manner, critically evaluate existing research studies, analyze and interpret data effectively, and present their research findings in a clear and concise manner [22]. Therefore, the fifth hypothesis of this study can be written as: research methodology skills are a component of research skills of future teachers (H5).

2.2. Technologies for the development of research skills

In the dynamic landscape of the modern digital era, the instrumental role of technologies and digital tools in enhancing teachers' research skills cannot be overstated. Through these resources, teachers gain access to extensive information and a plethora of valuable resources, fostering collaboration and knowledge exchange among educators and researchers. By using these technologies, teachers can enhance their knowledge, improve their research skills, and stay up to date with the latest advancements in the field of education.

Digital tools for literature searching and curation, OCWs, collaborative learning and discussion forums, data analysis software, and virtual and augmented reality simulations comprise the diverse array of technologies available to foster the development of teachers' research skills. Technological resources empower teachers with a wide spectrum of opportunities to cultivate their research expertise and expand their knowledge of cutting-edge research methodologies and techniques. Whether they are new to research or seasoned researchers, teachers can benefit from these technologies to enhance their research skills and stay current with the latest advancements in their field.

2.2.1. Digital tools for literature searching and curation

Digital tools for literature searching and curation such as Google Scholar, Scopus, and EndNote assist in finding and organizing research articles [23]. The use of digital tools for literature searching and curation is important in the development of research skills of future teachers for several reasons: i) efficient searching: more efficient and comprehensive search of large databases of academic literature is provided [24], [25]. This helps future teachers quickly find relevant articles and studies which can be used as a basis for their own research; ii) improved accuracy: the used algorithms to search databases ensure reduction of errors and improve accuracy in literature search; iii) easy organization and management: future teachers organize, categorize and manage their literature searches in an efficient manner making it easier to track their findings and use digital tools in research; iv) time-saving: time and effort invested to research processes can be saved while using these technologies, allowing teachers to focus on other important aspects of their study; and v) increased accessibility: a wider range of academic literature including articles and studies that may not be available in traditional library collections, can be accessed via special tools for literature searching.

Embracing digital tools dedicated to literature searching and curation is important for the development of research skills of future teachers as they provide more efficient, accurate, and comprehensive research processes. These tools can help future teachers save time, improve their research skills, and make their findings more accessible. Therefore, the sixth hypothesis is digital tools for literature searching and curation are significantly effective in the development of research skills of future teachers (H6).

2.2.2. Online courses and workshops

The platforms like Coursera, Udemy, and Khan Academy offer courses and workshops on research skills, statistics, and methodology. OCWs can play an important role in the development of research skills of future teachers for several reasons: i) flexibility future teachers can learn at their own pace and schedule

which can be especially beneficial for those with busy schedules or other commitments; ii) wide range of topics: the topics are related not only to various researches but also to methodology, data analysis, writing and publishing research papers, and much more; iii) access to experts OCWs are often taught by experts in their field, providing future teachers with valuable insights and practical advice for conducting research; iv) interactive learning inclusion of interactive elements such as discussion boards, group projects, and live Q&A sessions, which can help foster collaboration and critical thinking skills; and v) cost-effective greater cost-efficiency than of traditional in-person workshops and courses, makes it easier for future teachers to access valuable training and development opportunities.

OCWs can play an important role in the development of research skills of future teachers by providing flexible, comprehensive, and cost-effective training opportunities [26]. By participating in these programs, future teachers can gain new insights, skills, and knowledge that will help them to conduct research with confidence and effectiveness [27]. Hence, the seventh hypothesis of this study is designed as: OCWs are significantly effective in the development of research skills of future teachers (H7).

2.2.3. Collaborative learning and discussion forums

Communities like Reddit, Quora, and ResearchGate can provide a platform for teachers to discuss research topics, share findings, and receive feedback. Collaborative learning and discussion forums (CLDFs) play a crucial role in the development of research skills of future teachers [28] for several reasons: i) sharing of ideas and perspectives, a provided platform for future teachers helps them share their ideas, perspectives, and experiences related to research. This can foster new insights, improve critical thinking skills, and encourage the development of new ideas; ii) peer feedback, future teachers have an opportunity to receive feedback and suggestions from their peers which can be valuable for mastering their research skills and knowledge; iii) networking, discussion forums can help future teachers build networks with other researchers and experts in their field in order to access new resources, share information and make discoveries; and iv) improved communication skills, CLDFs can develop written and verbal communication skills which are essential for effective presentation of findings.

CLDFs are important for the development of research skills of future teachers. They provide a platform for learning, sharing, and networking which can help to improve research skills, foster new ideas and perspectives, and encourage the development of new knowledge and skills [29]. Subsequently, the following hypothesis can be concluded: collaborative learning and discussion forums are significantly effective in the development of research skills of future teachers (H8).

2.2.4. Data analysis software

Tools like SPSS, R, and SAS can help future teachers analyze data, make inferences, and visualize results. The use of data analysis software (DAS) is important in the development of research skills of future teachers for several reasons: i) efficient data analysis, software tools and techniques are necessary to quickly and accurately analyze large amount of data, save time, and minimize errors; ii) improved visualization, a range of tools for visualizing and presenting data, including graphs, charts, and tables help give more effective presentation of the research; iii) data manipulation, tools for cleaning, transforming, and manipulation are available within the software which makes it easier to work with large and complex datasets; and iv) increased accessibility, DAS is often designed to be user-friendly and accessible even to those with limited technical skills.

The use of DAS is important in the development of research skills of future teachers as it provides a range of tools and techniques for efficient, accurate, and effective data analysis [30]. By using these tools, future teachers can gain practical experience, develop new skills, and improve their research outcomes. Therefore, the ninth hypothesis of this study is interpreted as: data analysis software is significantly effective in the development of research skills of future teachers (H9).

2.2.5. Digital portfolios

Platforms like Google Drive, OneDrive, and Dropbox can help future teachers store, organize, and showcase their research projects [31]. Digital portfolios (DPs) are an important tool for the development of research skills of future teachers for several reasons: i) evidence-based reflection, a platform enables teachers to reflect on their research experiences, skills, and outcomes and to build an evidence-based record of their progress and achievements; ii) improved communication: research results can be presented in a clear and concise manner which improves communication skills and allows to share the findings more effectively; and iii) collaboration, DPs can be shared with peers, supervisors, and other stakeholders, allowing future teachers to collaborate and receive feedback on their research.

This tool is important for the development of research skills of future teachers as it provides a platform for reflection, collaboration, and career development, and can help improve communication skills, increase motivation, and enhance the overall quality of research outcomes [32]. Therefore, the tenth

hypothesis of this study is designed as: DPs are significantly effective in the development of research skills of future teachers (H10). The integration of the aforementioned technologies into teacher education programs can provide future teachers with the necessary skills to conduct research, analyze data, and communicate their findings effectively. The conceptual model proposed by this study and the hypotheses are presented in Figure 1.
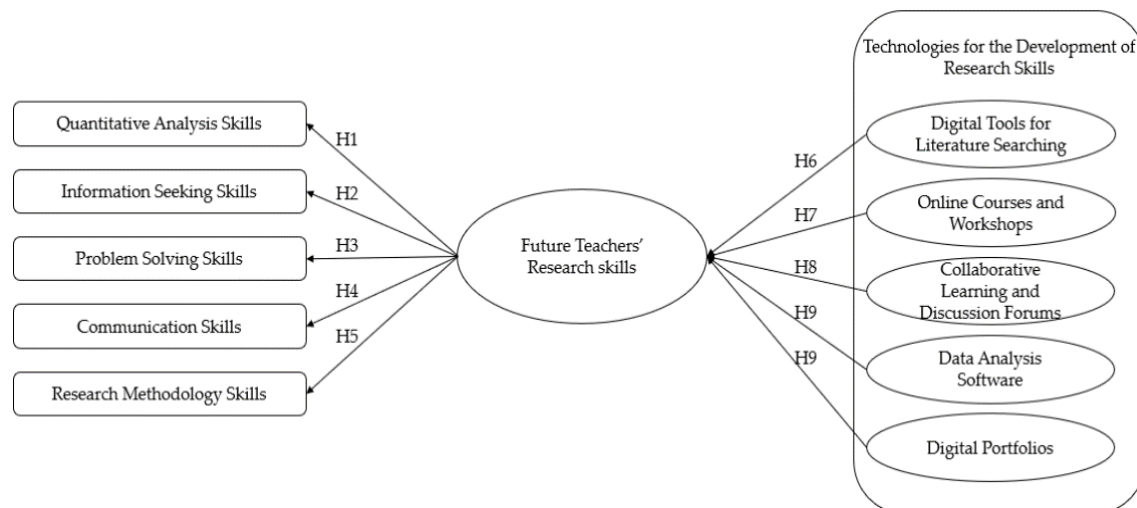

Figure 1. The proposed conceptual model of the study

3. RESEARCH METHOD

3.1. Data source

Participating graduate students at the University of Kazakhstan who participated in the Mathematical Olympiad constitute the statistical population of the present study. The number of participants who formed the statistical sample of the study was 100. In order to evaluate the conceptual model, a questionnaire was designed and administered among the statistical sample. The data collection was done in December 2022.

The designed questionnaire includes two main parts. In the first part, the research skills of the participants were evaluated, and in the second part of this questionnaire, the participants expressed their opinion about the impact of the mentioned technologies on the development of their research skills. It should be noted that this questionnaire was designed based on a 5-point Likert scale, where 1 means strongly disagree, 2 means disagree, 3 means have no opinion, 4 means agree, and 5 means strongly agree. The questions used to measure the variables of this research are presented in Tables 1 and 2.

3.2. Data analysis

In order to test the proposed model of the present study, structural equation modeling (SEM) was used using SmartPLS 4 software. In SEM, the relationship between research variables and questionnaire questions is called a measurement model. The measurement criteria of the measurement model are reliability and validity. In this study, Cronbach's alpha and composite reliability (CR) were used to measure the reliability of the measurement model, and the average variance extracted (AVE) was used to measure the validity [33]. Cronbach's alpha and CR can take a number between 0 and 1, where values above 0.7 are considered desirable because they represent the high reliability of the questions. Meanwhile, AVE evaluates the variances of each variable due to different questions and the desired scenario is that one question expresses more than 50% of the variances of the variable assigned to [34]. Therefore, values above 0.5 are acceptable. After the validity and reliability test, factor analysis is performed to ensure that the questions measure the variable well. Two criteria are used to evaluate factor analysis, namely loading factors should be above 0.7 and these loading factors should be statistically significant.

On the other hand, in SEM the structural model will test hypotheses. The structural model is the causal relationship between the main variables of the study. The criterion for measuring the structural model test is the significance of the path coefficients. The magnitude of the causal relationship is measured using the R^2 determination coefficient.

Table 1. Designed questions to evaluate the research skills of future teachers

Variables	Questions	Question code
Quantitative analysis skills	I feel confident using software for data analysis, such as SPSS or R.	Q1
	I am confident in my ability to select the appropriate statistical test for analyzing data.	Q2
	I feel comfortable interpreting the results of a regression analysis, including the coefficients and any assumptions made.	Q3
	I am familiar with the use of control variables in research and understand how they can impact the results of a statistical analysis.	Q4
	I am confident in my ability to perform a t-test to determine if there is a significant difference between two groups.	Q5
	I understand the difference between descriptive and inferential statistics and can give an example of when each would be used in research.	Q6
Information seeking skills	I am confident in using search engines to find information for research purposes.	Q7
	I am able to use library databases to locate relevant academic sources.	Q8
	I am confident in evaluating the credibility of the information I find online.	Q9
	I effectively organize and manage the information I gather for my research projects.	Q10
	I use interdisciplinary sources and perspectives in my research.	Q11
Problem solving skills	I am able to identify and define a research problem effectively.	Q12
	I am able to generate and consider multiple solutions to a research problem.	Q13
	I am able to evaluate the potential consequences of each solution.	Q14
	I am able to reflect on the outcome of a research problem and identify areas for improvement.	Q15
	I am able to work effectively in a team to solve a research problem.	Q16
Communication skills	I am able to effectively communicate research findings both verbally and in written form.	Q17
	I am confident in presenting my research findings in front of an audience.	Q18
	I am able to effectively use visual aids, such as slides and graphs, to enhance my research presentations.	Q19
	I am able to listen actively and effectively respond to feedback on my research.	Q20
	I am able to summarize and synthesize complex information for a general audience.	Q21
	I am able to use appropriate language, tone, and nonverbal cues in different research-related settings.	Q22
Research methodology skills	I am confident in designing a research plan or proposal.	Q23
	I understand well different research methodologies and their applications.	Q24
	I am comfortable with collecting, analyzing, and interpreting data for research purposes.	Q25
	I effectively communicate the results and findings of my research to others.	Q26
	I am able to critically evaluate the limitations and potential biases of my research methods and results.	Q27

Table 2. Designed questions to evaluate the effect of the technologies on research skills of future teachers

Variables	Questions	Question cods
Digital tools for literature searching and curation	I am confident to use Google Scholar, Scopus, and EndNote to find research articles.	Q28
	I effectively use these tools to organize and track of research articles for my projects.	Q29
	I evaluate well the relevance and reliability of the articles found using these tools.	Q30
	I frequently use these tools in my research projects.	Q31
	I understand well the features and capabilities of these tools for literature searching and curation.	Q32
OCWs	I often participate in OCWs to improve my research skills.	Q33
	I effectively apply the knowledge and skills gained from these OCWs in my research projects.	Q35
	I evaluate well the quality and relevance of these OCWs to my research needs.	Q36
	I prioritize well and manage my time to participate in these OCWs while balancing other responsibilities.	Q37
Collaborative learning and discussion forums	I find participating in discussion forums helpful in improving my research skills.	Q38
	I often participate in online discussion forums related to research topics.	Q39
	I find useful the feedback and suggestions I receive from other teachers in online discussion forums.	Q40
	I find that collaborating with other teachers in online discussion forums improves my understanding of research methodology.	Q41
	I believe that participating in online discussion forums with other teachers contributes to the development of my research skills.	Q42
Data analysis software	I believe that using data analysis software helps me better understand the results of my research.	Q43
	I often use data analysis software in my research process.	Q44
	I feel confident in using data analysis software for analyzing data and drawing conclusions.	Q45
	I think learning how to use data analysis software has improved my research skills.	Q46
	I believe that data analysis software has made my research process more efficient and effective.	Q47
DPs	I am familiar with DPs such as Google Drive, OneDrive, and Dropbox.	Q48
	I frequently use DPs for storing and organizing my research projects.	Q49
	I find DPs helpful in showcasing my research projects to others.	Q50
	I believe that DPs are essential in the development of collaborations in research projects.	Q51
	I believe that using DPs impacted my research process and outcomes.	Q52

4.   RESULTS

First, the validity and reliability of the questions designed to evaluate the proposed research model were measured. Table 3 shows that the model variables have good reliability because both Cronbach's alpha coefficient and CR for all model variables are above the threshold of 0.7. On the other hand, the value of AVE for all variables is above 0.5, which shows the appropriate convergent validity of the model.

Table 3. The results of Cronbach's alpha, CR, and AVE

Variables	Cronbach's alpha	CR	AVE
Quantitative analysis skills	0.764	0.864	0.803
Information seeking skills	0.837	0.867	0.509
Problem solving skills	0.885	0.935	0.523
Communication skills	0.845	0.915	0.797
Research methodology skills	0.89	0.910	0.837
Digital tools for literature searching and curation	0.787	0.847	0.530
Online courses and workshops	0.872	0.922	0.651
Collaborative learning and discussion forums	0.857	0.917	0.814
Data analysis software	0.823	0.833	0.805
Digital portfolios	0.900	0.920	0.642

After confirming the reliability and validity of the model, exploratory factor analysis was performed using SEM method. SEM has two criteria for accepting these factors (designed questions). First, the loading factors must be above 0.7 and second, these loading factors must be significant at least in the 95% confidence interval (i.e., $p<0.05$). If any of these conditions are flawed, that question must be removed from the final assessment of the conceptual model. In Table 4, the questions that did not meet at least one of these conditions (and were finally removed from the model) are highlighted. For example, two questions Q2 and Q3 were removed from measuring the variable of quantitative analytical skills, and questions Q8 and Q11 were removed from measuring the variable of information seeking skills.

Table 4. The results of the measurement model test

Variables	Question codes	Loading factor	P values	Variables	Question codes	Loading factor	P values
Quantitative analysis skills	Q1	0.930	0.021	Digital tools for literature searching and curation	Q28	0.970	0.050
	Q2	0.650	0.083		Q29	0.590	0.092
	Q3	0.590	0.057		Q30	0.970	0.050
	Q4	0.820	0.017		Q31	0.757	0.022
	Q5	0.710	0.019		Q32	0.570	0.085
	Q6	0.800	0.048	Online courses and workshops	Q33	0.660	0.052
Information seeking skills	Q7	0.790	0.036		Q34	0.940	0.013
	Q8	0.580	0.066		Q35	0.970	0.030
	Q9	0.900	0.040		Q36	0.950	0.023
	Q10	1.000	0.034		Q37	0.830	0.045
	Q11	0.510	0.071	Collaborative learning and discussion forums	Q38	0.920	0.011
Problem solving skills	Q12	0.720	0.040		Q39	0.570	0.038
	Q13	0.780	0.049		Q40	0.610	0.028
	Q14	0.730	0.067		Q41	0.860	0.026
	Q15	0.930	0.020		Q42	0.760	0.006
	Q16	0.580	0.058	Data analysis software	Q43	0.710	0.039
Communication skills	Q17	0.950	0.045		Q44	0.710	0.036
	Q18	0.670	0.086		Q45	0.580	0.062
	Q19	0.900	0.043		Q46	0.570	0.077
	Q20	0.640	0.034		Q47	0.790	0.018
	Q21	0.820	0.013	Digital portfolios	Q48	0.590	0.088
	Q22	0.810	0.067		Q49	0.740	0.011
Research methodology skills	Q23	0.570	0.075		Q50	0.920	0.028
	Q24	0.920	0.036		Q51	0.650	0.086
	Q25	0.940	0.035		Q52	0.760	0.029
	Q26	0.590	0.075				
	Q27	0.927	0.044				

In SEM, the structural model was used to test the relationships between the main model variables. In the structural model, to confirm the causal relationships between the variables, the path coefficients must be significant in a confidence interval of at least 95% (i.e., $p<0.05$). Table 5 shows that the path coefficients

related to H1, H3, H4, H5, H6, H7, H8, and H9 are all significant. Therefore, the hypotheses associated with them are considered to be confirmed. Meanwhile, the path coefficients related to H2 and H10 are not significant which means that the hypotheses associated with them are not confirmed. In addition, the results show that R^2 is equal to 0.734 which is a very considerable value.

Table 5. Hypothesis testing results

Hypotheses		β	Standard deviation	P values	Result
Quantitative analysis skills ->research skills	H1	0.514	0.126	0.04	Confirmed
Information seeking skills ->research skills	H2	0.856	0.135	0.051	Not confirmed
Problem solving skills ->research skills	H3	0.759	0.083	0.042	Confirmed
Communication skills ->research skills	H4	0.471	0.118	0.018	Confirmed
Research methodology skills ->research skills	H5	0.382	0.068	0.032	Confirmed
Digital tools for literature searching and curation ->research skills	H6	0.407	0.035	0.033	Confirmed
Online courses and workshops ->research skills	H7	0.403	0.108	0.012	Confirmed
Collaborative learning and discussion forums ->research skills	H8	0.493	0.066	0.047	Confirmed
Data analysis software ->research skills	H9	0.67	0.056	0.05	Confirmed
Digital portfolios ->research skills	H10	0.611	0.070	0.052	Not confirmed

5. DISCUSSION

The current study presents quantitative empirical evidence supporting the inclusion of dimensions such as quantitative analysis skills, problem-solving skills, communication skills, and research methodology skills within the comprehensive framework of future teachers' research skills. Quantitative analysis skills encompass the capacity to collect, analyze, and interpret numerical data, facilitating informed decision-making and hypothesis testing. These abilities also facilitate the identification of patterns and trends, enabling accurate predictions based on research findings. This finding aligns with the existing literature, which emphasizes the importance of quantitative analysis in conducting rigorous research [35], [36]. Problem-solving skills involve a systematic and logical approach to identifying, analyzing, and resolving research problems. In research, these skills are fundamental, fostering a critical and analytical mindset when confronted with complex research challenges. Additionally, they cultivate the development of creative and innovative solutions, guiding informed decision-making based on the best available evidence.

This finding supports prior research that emphasizes the importance of problem-solving abilities in conducting research effectively [37], [38]. Communication skills are instrumental in effectively conveying research findings and ideas to diverse audiences. Within the research context, these skills facilitate the dissemination of research findings and meaningful engagement in dialogues with others. Furthermore, they contribute to the cultivation of clear and concise writing skills, essential for publishing research in academic journals and delivering research presentations at conferences. This result is consistent with previous studies that highlight the role of effective communication in various aspects of research, including dissemination of findings and collaboration with peers [39], [40].

Research methodology skills refer to the ability to plan, design, and execute research projects in an ethical and rigorous manner. These skills are crucial in research as they allow future teachers to carry out research that is well-designed and well-executed and to ensure that research findings are robust and reliable. They also help in the development of critical thinking and analytical skills, which are essential for evaluating the quality of research and for making informed decisions about research. This result is consistent with the literature, which emphasizes the significance of sound research methodology knowledge and application for conducting high-quality research [41], [42].

On the other hand, the findings revealed that digital tools for literature searching and curation, OCWs, collaborative learning and discussion forums, and data analysis software positively impact the research skills of future teachers. The use of these technologies can enhance the research skills of future teachers in various ways. This finding is in line with previous research highlighting the benefits of digital tools in enhancing information retrieval, organization, and synthesis in research [43], [44]. Digital tools for literature searching and curation, such as Google Scholar, Scopus, and EndNote, allow future teachers to quickly and effectively search for relevant literature, saving time and effort compared to traditional methods. By using these tools, future teachers can remain abreast of the most recent research in their respective fields and stay apprised of prevailing trends and breakthroughs, facilitating their ongoing knowledge acquisition and awareness. OCWs provide future teachers with opportunities to learn about research methods, statistics, and methodology in a structured and interactive environment. Such platforms allow for a flexible and convenient way for future teachers to improve their research skills and gain knowledge from experts in the field. This finding aligns with the literature, which emphasizes the potential of online learning platforms and workshops in enhancing research competencies [45].

Collaborative learning and discussion forums provide future teachers with a platform to connect with peers and experts, engage in discussions and debates, and receive feedback on their research. Engaging in such interactions can expand their comprehension of research topics, foster the development of critical thinking skills, and enhance their proficiency in communication. This result is consistent with previous studies that highlighted the benefits of collaborative learning environments for research skill acquisition, knowledge sharing, and critical thinking [46], [47]. Future teachers can benefit from data analysis software such as SPSS, R, and SAS, which enable them to proficiently analyze data, draw insightful inferences, and visually represent results. Such software fosters the development of improved data interpretation skills and enhances the ability to effectively communicate research findings.

The significance of integrating digital technologies into the education of future teachers is underscored by these findings, presenting compelling evidence for their incorporation to enhance research skills. The positive impact observed on the research skills of future teachers highlights the compelling rationale for integrating these technologies into the educational process. This result is consistent with previous literature emphasizing the importance of software tools for data analysis and statistical techniques in research practice [36], [48].

However, this study failed to provide evidence to prove that information seeking skill is one of the dimensions of future teachers' research skills. The lack of evidence to support the hypothesis could have several reasons. One possible explanation is that the participants in the study might not have been using information seeking skills extensively in their research activities. It could also be that information seeking skills are not a critical component of research skills for this particular group of students. It is important to consider these factors in future research to better understand the role of information seeking skills in the research skills of future teachers. Additionally, more in-depth and nuanced studies should be conducted to determine the precise nature of the relationship between information seeking skills and research skills. Furthermore, exploring the impact of different types of information-seeking skills on various aspects of research skills can also provide valuable insights into this relationship.

The study findings revealed that the research skills of future teachers did not exhibit a significant impact because of using DPs. Possible explanations for this outcome can be considered. Primarily, the adoption of DPs might not be as prevalent among future teachers compared to other technologies such as online courses, collaborative learning and discussion forums, or data analysis software. Consequently, it is plausible that the participants in the study did not have sufficient exposure to DPs to witness their influence on their research skills. Secondly, it is possible that the use of DPs is not as intuitive or straightforward as other technologies, meaning that future teachers may struggle to effectively utilize them in their research processes. Finally, it is possible that other factors such as access to technology or support from academic institutions may limit the use of DPs and their impact on research skills.

5.1. Recommendations

Based on the findings of the current study, the following recommendations can be made to enhance the research skills of future teachers. First, the emphasis on the use of digital tools for literature searching and curation: According to the findings, digital tools for literature searching and curation have a significant positive impact on research skills, it is recommended that future teachers be encouraged to use these tools regularly as part of their research process. By doing so, they can enhance their efficiency in locating relevant literature while effectively organizing their findings, thereby optimizing their research experience. Secondly, online courses and workshops. Given the importance of OCWs in developing research skills, it is recommended that future teachers be encouraged to enroll in courses and workshops that will help them gain new insights and knowledge in their field of research.

Third, collaborative learning and discussion forums. The findings revealed that collaborative learning and discussion forums have a significant positive impact on research skills, it is recommended that future teachers be encouraged to engage in regular discussions with other researchers. Engaging in such exchanges offers a valuable platform for sharing findings and receiving constructive feedback, playing a crucial role in improving their research skills. Fourth, data analysis software. It is also disclosed that data analysis software has a significant positive impact on research skills, and it is recommended that future teachers be encouraged to use these tools as part of their research process. Consequently, they can enhance their efficiency in data analysis, ensure more precise inferences, and facilitate a more effective visualization of results. Lastly, encourage the use of digital portfolios. Although the present study failed to find a significant positive impact of DPs on research skills, it is recommended that future teachers be encouraged to use these tools to store, organize, and showcase their research projects. Employing DPs can assist them in better tracking their progress and emphasizing their achievements, thereby contributing to a more comprehensive research experience.

5.2. Theoretical contributions

The current study made a significant contribution to the existing literature on the development of research skills in future teachers. It expanded the existing understanding of the impact of technology on the development of research skills by identifying the specific technologies that are effective in this process. By examining the existing literature and presenting empirical evidence, the study provided a comprehensive overview of the current state of technology in education and its role in the development of research skills in future teachers. The results of this study can be used by educators, researchers, and policy makers as a foundation for future research in this area.

5.3. Practical contributions

The identification of specific technologies that are effective in the development of research skills in future teachers provides educators with a roadmap for implementing technology in their classrooms. The results can be used to inform the design and implementation of professional development programs for teachers, helping them develop the necessary research skills to keep pace with the rapidly evolving technology landscape. Additionally, the results of this study can also be used by educational institutions and organizations to guide their investments in technology, ensuring that they are using the most effective tools for developing the research skills of their teachers.

5.4. Limitations

There are several limitations that should be considered in the interpretation of the results of our study. Firstly, the sample size used in the study may not be representative of the entire population of future teachers. It was limited to graduate students participating in the math Olympiad, which may not fully reflect the diverse backgrounds and experiences of future teachers. Secondly, the study was limited to a cross-sectional design, which means that the data were collected at a single point in time. This design does not allow for the examination of cause and effect relationships between the variables and limits the ability to make inferences about the direction of the relationship. Finally, the study relied on self-reported data, which may not be accurate or reflect the true beliefs or behaviors of the participants. Participants may have responded in a socially desirable manner or may have had difficulty accurately recalling their experiences with the technologies.

6. CONCLUSION

In conclusion, this study aimed to provide empirical evidence on the dimensions of research skills of future teachers, specifically graduate students participating in math Olympiads. The results of the study showed that quantitative analysis skills, problem-solving skills, communication skills, and research methodology skills are the dimensions of research skills of future teachers. It is also found that digital tools for literature searching and curation, online courses and workshops, collaborative learning and discussion forums, and data analysis software have a significant positive impact on the research skills of future teachers. However, the present study failed to provide evidence that digital portfolios affect research skills and that information seeking skills are dimensions of research skills of future teachers.

The generalization of the findings encounters limitations, including the small sample size and the self-reported nature of the data collected. Despite these limitations, the findings of this study provide valuable insights into the development of research skills in future teachers. Based on these findings, it is recommended that future teachers receive training and support in the use of digital tools for literature searching and curation, participate in OCWs, engage in collaborative learning and discussion forums, and receive training in data analysis software. In conclusion, the development of research skills in future teachers is crucial for their success in the field and should be a priority for educational institutions. Overall, the findings of the research emphasize the significance of technology in fostering research skills among future teachers and offer valuable insights for individuals involved in the education sector. By presenting a comprehensive overview of the current state of technology in education and its impact on research skills, this study makes a significant contribution to the field and provides a foundation for future research in this area.

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