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Factors Affecting the Competency of Applying Information and Communication Technology in Educational Scientific Research of Pedagogical Students in Vietnam

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***Abstract*—The application of information and communication technology in general and educational scientific research is developing rapidly, especially in Vietnam, where integrating Information and Communication Technology (ICT) in education is gaining momentum as part of the national digital transformation agenda. However, there remains a gap in understanding how pedagogical students, who are future educators, apply ICT in their scientific research activities. This study investigates the factors influencing the competency of pedagogical students to apply ICT in Educational Scientific Research (ESR), grounded in the theoretical frameworks of the Technology Acceptance Model, Social Learning Theory, and Theory of Planned Behavior. The authors identify potential factors by synthesizing existing research about factors affecting students' scientific research competencies and ICT competencies. This study uses the Delphi method because of the complexity of the factors and the need to gather expert consensus in refining and validating these elements, which was achieved through three rounds of expert consultation. The results revealed 18 key factors significantly impacting students' competence in effectively integrating ICT into their educational research activities. These factors span various domains, including institutional policies, financial support, ICT infrastructure, curriculum design, and individual student characteristics such as ICT skills, foreign language proficiency, and self-directed learning capabilities. Among these, institutional policies supporting ICT integration, financial support, ICT infrastructure, students' ICT skills, and self-directed learning capabilities were the most significant and impactful. The findings offer valuable insights for educational institutions seeking to improve students' research competencies by implementing targeted interventions that harness the potential of ICT in scientific research.**

***Keywords*—Delphi method, factors affecting, educational scientific research, pedagogical students, competency of applying ICT in educational scientific research**

I. Introduction

Currently, digital transformation is an inevitable trend in training and research activities. The field of scientific research in general, and Educational Scientific Research (ESR) in particular, is no exception to this trend. The application of Information and Communication Technology (ICT) in scientific research is an area with significant potential and has demonstrated the effectiveness of these tools, especially in the digital age [1, 2]. ICT tools and applications for providing research data and information are diverse and abundant. The use of ICT tools in scientific research greatly supports the research process, enhancing the quality and efficiency of this activity [2, 3]. ICT tools have been developed to assist researchers in various activities within the research process, such as surveying, analyzing, searching, presenting information, and presenting research results [4]. Despite their many advantages, previous research also highlighted the challenges of using ICT in scientific research, such as obstacles related to access, technological infrastructure, and researchers' ICT skills. It limited the full use of these tools [2, 5, 6]. Although these studies identify challenges and provide insights into specific ICT applications in research, they do not fully address the competences necessary to integrate ICT into the entire ESR process, especially among pedagogical students.

According to Dinh N.V. [7], the competency in applying ICT in educational scientific research of pedagogical students is defined as the ability to effectively use technological tools and resources to communicate, create, disseminate, store, and manage information efficiently in educational scientific research activities. The competency in applying ICT in educational scientific research of pedagogical students is a complex structure that encompasses knowledge, skills, and attitudes in using ICT throughout the research process to effectively carry out educational scientific research tasks. A person with competency in applying ICT in educational scientific research demonstrates the ability to integrate ICT into all stages of the research process. This competency is a system comprising various sub-competencies related to the use of ICT in key activities of the educational scientific research process. It is one of the constituent elements of pedagogical students' competency in educational scientific research. Enhancing and developing educational scientific research competency for pedagogical students is a crucial component of the training programs at teacher education institutions. Therefore, the competency in applying ICT in educational scientific research significantly impacts the quality and effectiveness of pedagogical students' research activities. However, existing studies on student research competencies often overlook the intersection of ICT skills and research competencies, focusing more broadly on ICT proficiency in academic contexts or general research skills without addressing how these competencies converge in the specific context of ESR [8–21].

Numerous studies have addressed the factors influencing students' research competency [8–21]. Several studies have also identified factors influencing students' ICT competency [22–33]. However, these studies treat ICT and research competency separately, and few have explored the overlap between these domains, particularly within the context of pedagogical students and their Educational Scientific Research (ESR) activities. Furthermore, no studies have yet identified the factors affecting the competency in applying ICT in educational scientific research of pedagogical students, leaving a significant gap in the literature regarding how these two areas intersect. This study aims to fill this gap by focusing on factors influencing this specific competence that have not been addressed in previous studies.

In this study, based on the theoretical foundations of the Technology Acceptance Model (TAM) [34], the Social Learning Theory (SLT) [35], and Theory of Planned Behavior (TPB) [36], the authors have inherited and synthesized the factors influencing students' research competency and ICT competency. These theories are chosen because they provide a robust framework for understanding the use and adoption of technology in educational environments. TAM is particularly relevant for analysing the usefulness and ease of use of ICT tools in students, which are critical factors in determining their willingness to integrate them into their research activities. The SLT emphasizes the role of the social environment, including interaction with colleagues and mentors, in shaping the behavior of students implementing ICT and makes it very applicable in research collaboration and supervision. The TPB focuses on how students' attitudes, subjective norms, and perception of behavioral control influence their intention to apply ICT in research and aligns well with the multifaceted nature of developing research competencies. These theoretical frameworks provide comprehensive lenses through which to explore the complex interplay of cognitive, behavioral, and contextual factors influencing students' ICT competency in ESR. Consequently, the authors initially identified the factors affecting the competency in applying ICT in educational scientific research of pedagogical students. The Delphi method was then employed to gather expert opinions to standardize and accurately determine the influencing factors of this competency.

II. Literature Review

A. Factors Influencing Students' Scientific Research Competency

The factors influencing students' scientific research competency have been a subject of interest for many researchers. These factors can be categorized into several groups based on the following studies:

Group of Environment and conditions for learning and scientific research factors: Policies that encourage scientific research and the fairness of these policies [8, 9], lack of research learning conditions, lack of research activities, and insufficient funding for research [9, 16]. Quality assurance mechanisms, accreditation, and accountability implementation; research funding institutions and collaboration mechanisms. The encouragement from educational institutions, policies, and incentives provided by schools to promote students' research abilities and attract students to research activities [9, 14], and the lack of time dedicated to research [16]. Ilyashenko [13] suggested that factors affecting students' research competency include the school, teachers, and parents, as well as attitudes toward scientific perception and the environment.

Group of Influence from surrounding people: Pressure from supervisors, collaboration with peers [8, 16]; guidance from supervisors, and the enthusiasm of research advisors [16]. Creating a unique scientific competence atmosphere among students is identified as a crucial factor in forming the model of scientific competence in university students [19]. The development of research competency is closely related to the organization of educational and scientific research activities in the university environment, emphasizing the importance of the educational environment in fostering research competency [15]. Additionally, the level of research competency development in students is significantly related to the academic term, indicating that the educational environment and curriculum design impact the progression of research competency [37]. The role of the supervisor and active participation in cultivating research skills in students is also highlighted in Mombekova's [15] study.

Group of factors related to awareness of the usefulness of research: Awareness of the role and significance of research activities, and awareness of the usefulness of research [9, 20, 21].

Group of factors related to individual student competency: Academic performance, knowledge of using ICT in research, skills in using ICT in research, and research experience [9, 20, 21].

Group of factors related to individual student characteristics: Gender [11, 21], self-confidence [16]; intention to enhance scientific research competency [8, 9]. Fu *et al.* [17] identified several key factors influencing research competency, including degree type, student level, interest in scientific research, time invested in scientific research, statistical analysis methods, writing skills, and charting ability. These are factors related to the competency and qualities of students.

Meanwhile, Kim *et al.* [10] found that research competency differs among factors such as gender, age, teaching experience, major, and university location. However, belief in scientific research competency does not always align with actual performance, highlighting the importance of mentorship and the need for training to develop scientific research competency [12]. Additionally, students' participation in research groups and scientific research student clubs is associated with higher scores in research competency, underscoring the positive impact of mentors and collaborative research experience on the development of scientific research competency [18].

B. Factors Influencing Students' ICT Competency

Students' ICT competency is influenced by various factors, with learning conditions and the environment playing a crucial role. First, the availability of ICT infrastructure and resources, accessibility, and the ability to utilize these resources positively impact students' learning and development of ICT competency [28]. Students' technological skills are enhanced when the academic environment is integrated with technology and provides favorable conditions [27]. These factors create a solid foundation for students to develop ICT skills for learning and research. Research in Pakistan concluded that the availability, accessibility, comprehensive access, and usability of ICT resources positively impact students' learning and scientific research [28].

Individual factors also significantly influence students' ICT competency. Age and gender can affect students' technological proficiency [25]. However, studies present conflicting results regarding the extent of these factors' influence [38]. Additionally, educational background and initial training in ICT contribute significantly to the formation and development of students' technological competency. Students with better ICT education and training tend to have higher technological proficiency [25]. Intrinsic factors for students, such as ICT usage skills and perceived usefulness of ICT, along with external factors like the availability of resources, greatly influence students' use of ICT [26].

Experience with computers is another strong factor impacting students' ICT competency. Students with prior computer exposure or more time spent using them often possess higher ICT competency. Regular exposure and practice with computers familiarize students with technological tools and improve their ability to use them effectively in learning and work [27, 31, 32].

Finally, the surrounding environment and support from schools and teachers also significantly affect students' ICT competency. This support includes providing resources, favorable learning conditions, motivation, and a positive attitude toward ICT from teachers. When students receive support and encouragement from their learning environment, they are more motivated to develop ICT skills, enhancing their learning and research capabilities [22, 29]. In resource-constrained settings, even providing basic infrastructure and access to general technical knowledge requires more creativity and coordinated efforts from school leadership and instructors [23].

In summary, although several studies have explored factors influencing research competency and ICT competency individually, there has been limited research on the intersection between these two areas, particularly in the context of pedagogical students' ESR. By synthesizing these studies, this research seeks to fill this gap and identify the specific factors that influence the competency in applying ICT in ESR of pedagogical students. Moreover, this research integrates insights from the TAM, the SLT, and the TPB to examine how technological, social, and behavioral factors jointly influence this competency. This integration is critical to understanding the multi-faceted nature of ICT application in research and providing practical insights for enhancing pedagogical students' research capabilities in the digital era.

III. Factors Influencing the Competency of Applying ICT in Educational Scientific Research of Pedagogical Students

In order to identify factors influencing student science research abilities and ICT competence, this study synthesized factors influencing student competence and ICT competence on the following theoretical basis:

The TAM argues that users' acceptance of new technologies depends on two key factors: perceived usefulness and perceived ease of use [34]. Perceived usefulness is defined as the extent to which individuals believe that using a particular technology improves their performance at work. When researchers understand that ICT improves research efficiency, they are more likely to adopt it in scientific research. The perceived ease of use refers to the degree to which technology is free of effort and complexity. If ICT is designed to be user-friendly, researchers will encourage them to integrate it into their work. Therefore, factors influencing students' competence in using ICT in ESR include awareness of the role and importance of ESR activities, knowledge of the effectiveness of ICT in ESR, and career goals.

Bandura's Social Learning Theory emphasizes the role of observation and social interaction in learning new skills [35]. Factors such as the learning environment, peer support, and practice opportunities play crucial roles in developing ICT competency in scientific research. A supportive learning environment, where researchers can learn from each other and gain access to new technologies, will enhance their ICT competency. Therefore, the factors related to the environment and learning conditions for scientific research include policies encouraging scientific research, ICT usage in research, funding support, technical infrastructure, ICT-supporting research, and time allocated for ESR.

Peer support is another important factor. Studies have shown that support from peers and the academic community can increase an individual's confidence and motivation to use ICT. In this study, it is proposed that influence from those around, such as pressure from supervisors, guidance from supervisors, enthusiasm of supervisors, and collaboration with peers, impacts the competency of applying ICT in ESR among pedagogical students.

The TPB is a psychological model that helps predict and understand human behaviors. TPB posits that an individual's behavior is influenced by Behavioral Intention, Attitude Toward the Behavior, Subjective Norms, and Perceived Behavioral Control [36]. Behavioral Intention: Researchers who strongly intend to use ICT in their research are likelier to carry out that behavior. Attitude Toward the Behavior: This refers to the positive or negative feelings toward using ICT in research. Subjective Norms: The influence of society, peers, or organizations on the decision to use ICT. Perceived Behavioral Control: The degree to which an individual believes they can control the use of ICT in their work. Perception of behavior in applying ICT in ESR among pedagogical students involves their views and perspectives on using ICT in ESR. When an individual perceives the application of ICT in ESR as beneficial, both personally and socially, they are more motivated to implement ICT in ESR. Conversely, if an individual considers the application of ICT in ESR as unimportant or unnecessary, they will have less motivation, or even no intention, to apply ICT in ESR.

This study examines the perceived usefulness of applying ICT in ESR and students' perceptions of it. The factors identified in this context include awareness of the role and significance of scientific research, awareness of the usefulness of using ICT in scientific research, and career aspirations.

Perceived behavioral control in the context of applying ICT in ESR is understood as a group of personal factors used to assess one's ability to perform the behavior successfully. This study considers factors such as students' competency and individual characteristics. Specifically, the factors identified include Cumulative Grade Point Average (GPA); knowledge of using ICT in scientific research; skills in using ICT in scientific research; research experience; gender; self-confidence; and intention to improve ICT competency in research.

These three theoretical models complement each other by providing a more comprehensive framework for understanding the various dimensions of ICT application in ESR. TAM provides insights into the technological factors (Perceived Usefulness and Perceived Ease of Use) that affect students' motivation to adopt students '. The SLT emphasizes the social and environmental aspects, highlighting the importance of peer support, institutional policies, and a collaborative learning environment in fostering ICT competency. Meanwhile, TPB adds a behavioral perspective by explaining how students' attitudes and perceptions control their ICT usage and influence their behavior. By integrating these three models, this study offers a well-rounded approach to examining the technical, social, and psychological factors that influence the competency of applying ICT in ESR.

A comprehensive summary of the factors influencing the use of ICT in ESR is presented in Table 1, which also serves as the initial theoretical framework proposed for conducting expert interviews using the Delphi method (which will be detailed in the subsequent section of the study).

Table 1. Factors influencing the competency of applying ICT in ESR among pedagogical student

Group of factors	Factors	Influencing students' scientific research competency	Influencing students' ICT competency
Environment and conditions for learning and scientific research	Policies encouraging scientific research and ICT usage in research	[8, 9, 14, 15]	[22, 23]
	Funding support	[16]	[26]
	Technical infrastructure, ICT-supporting research	[9, 16]	[27–30].
	Time allocated for ESR	[16, 17]	[30–32]
Influence from surrounding people	Pressure from supervisors	[8, 15, 16]	[23]
	Guidance from supervisors	[15, 16, 18]	
	Enthusiasm of supervisors	[16]	[23]
	Collaboration with peers	[14, 18, 19]	
Awareness of the usefulness of research	Awareness of the role and significance of ESR activities	[16]	[33]
	Awareness of the usefulness of ICT in ESR		[26, 33]
	Career aspirations	[20]	[24]
Individual student competency	Cumulative GPA	[20, 21]	[25].
	Knowledge of using ICT in scientific research	[20, 21]	[26, 27, 30]
	Skills in using ICT in scientific research	[20, 21]	[26, 27]
	Research experience	[10]	
Individual student characteristics	Gender	[10, 11, 21]	[25, 30]
	Self-confidence	[12, 16]	[33]
	Intention to improve ICT competency in research	[8, 13]	

IV. METHODS

This study employs the Delphi method to explore the factors influencing the competency of applying ICT in ESR among pedagogical students. The Delphi method was first developed by the Research and Development (RAND) Corporation in the 1960s to explore ideas and seek consensus among experts [39, 40]. According to Keeney *et al.* [41], the Delphi method uses an iterative process to achieve consensus from various experts on a specific issue. The steps in the Delphi process include:

Step 1: Build a Delphi implementation team.

Step 2: Select a team of experts involved in the Delphi process. Scholars who are faculty members at universities in Vietnam with extensive experience in ESR and who have previously guided students in scientific research were invited to participate in this study. The criteria for selecting experts include university lecturers with a master's degree or higher, aged 30 or older. These people have guided students in scientific research. To enrich the consultation audience, the authors also suggested that some bachelor and graduate students with much experience in conducting research be invited to consult. These criteria ensure a broader perspective, allowing us to gather insights from experienced faculty and those actively involved in the research process as students. The research team invited 40 educational experts who met these criteria. All experts had a personal connection with the co-authors of the study. According to McKenna [42], a high response rate in consecutive rounds of Delphi studies is crucial, and personal relationships with the researchers can help increase this rate. Thirty-four individuals agreed to participate in the first round of the study (an acceptance rate of 85%). Endacott *et al.* [43] recommend that a Delphi study's appropriate number of participants ranges from 20 to 50. Therefore, the research team met this requirement with 34 participants in the first round.

Step 3: Develop the index and questions. We developed the first-round survey questionnaire based on the synthesis of relevant literature concerning the factors influencing the competency of applying ICT in ESR among pedagogical students (see Table 1) and consultations with educational experts. The questionnaire consists of three main sections: The first section of the questionnaire addresses the personal characteristics of the participants. The second section includes 15 items rated on a 5-point scale (1-Not important at all to 5-Very important), evaluating the significance of factors influencing the competency of applying ICT in ESR among pedagogical students. These evaluations also ask participants to elaborate on their responses through corresponding open-ended questions. The items were developed based on previous research on our topic and synthesized from the relevant literature as analyzed earlier (Table 1). The third section of the survey contains two open-ended questions. The first question asks participants if any terms in the 15 items of the second section need to be revised or adjusted. The second question asks respondents, based on their experience, to suggest any new content beyond the initial 15 items that might influence the competency of applying ICT in ESR among pedagogical students. Participants were also asked to provide explanations for their suggestions.

Step 4: Conducting the first round of the Delphi method and analyzing responses. After receiving the experts' responses, the research team synthesized and analyzed the results based on the Knowledge Acquisition for Multiple Experts with Time scales (KAMET) principle (see Table 2). The KAMET principle evaluates the importance of each factor (qi) at different stages by considering a combination of statistical values, including the mean value (Mqi), the quartile deviation (Qqi), and the percentage of experts who changed their assessment Rating Variant (Vqi) [39, 44].

Step 5: Conducting subsequent rounds of the Delphi method. Questionnaires, after being updated with newly proposed factors or having removed factors that did not meet the KAMET criteria in the previous round, are sent to each expert for their opinion on the level of agreement and to assess the stability of the responses. The questionnaire sent to the experts also includes their previous round's evaluation and the average evaluation of the items being reviewed. This helps experts reconsider whether they want to change their opinions on the items in the current round.

Step 6: Analyzing expert feedback. Based on recalculating the statistical values (Mqi, Qqi, Vqi), the results are analyzed following the KAMET principle. The analysis results determine whether further rounds should be conducted.

Step 7: Analyzing and synthesizing the results. The author uses Microsoft Excel to calculate the survey data from the experts.

Table 2. The KAMET rule analyzes assessments from experts using the Delphi method [44]

Condition	Round t of the Delphi questionnaire	Round t+1 of the Delphi questionnaire	Round t+2 of the Delphi questionnaire
1	$M_{qi} \geq 3.5$	If $M_{qi} \geq 3.5$ and $Q_{qi} \leq 0.5$ and V_{qi} < 15% then q_i is accepted.	
2	$M_{qi} < 3.5$	If $M_{qi} < 3.5$ and $Q_{qi} \leq 0.5$ and $V_{qi} \leq 15\%$ then q_i is not accepted.	
3	$M_{qi} < 3.5$	If $M_{qi} \geq 3.5$ or $V_{qi} > 15\%$ then continue with round $t + 2$.	If $M_{qi} \geq 3.5$ and $Q_{qi} \leq 0.5$ and $V_{qi} \leq 15\%$ then q_i is accepted.

V. Result

A. Round 1 Survey Results

In the first round, the Delphi team distributed the survey link to individuals who had agreed to participate in the Delphi study so they could complete the questionnaire. Table 3 outlines the personal characteristics of the 34 participants. These experts are currently employed at various universities in Vietnam, including Vietnam National University, Hanoi; Thai Nguyen University; Dong Thap University; Tay Bac University; and Van Lang University, among others. Specifically, among the 34 respondents, the majority were aged between 31 to 35 (15 participants, 44.1%) or 41 to 50 (13 participants, 38.2%). The remaining participants were either over 51 years old (14.7%) or under 30 years old (1 participant).

Table 3. Personal characteristics of study participants

Participant characteristics		Round 1		Round 2		Round 3	
		N=34	%	N=27	%	N=19	%
Age	Under 30	1	2.9	1	3.7	0	0.0
	From 31 to 40	15	44.1	12	44.4	3	15.8
	From 41 to 50	13	38.2	10	37.0	12	63.2
	Over 51 years old	5	14.7	4	14.8	4	21.1
Academic degree	Bachelor and graduate student	1	2.9	1	3.7	0	0.0
	Master and currently a PhD student	10	29.4	8	29.6	3	15.8
	PhD	23	67.6	18	66.7	16	84.2
Scientific positions	Associate Professor	9	26.5	5	18.5	6	31.6
	Professor	1	2.9	1	3.7	1	5.3
Time working in the education sector	Under 5 years	3	8.8	3	11.1	0	0.0
	From 5 to 10 years	2	5.9	1	3.7	1	5.3
	From 10 to 15 years	12	35.3	11	40.7	6	31.6
	From 15 years or more	17	50.0	12	44.4	12	63.2
Number of scientific research topics of students who participated in guidance	Less than 10 student research topics	15	44.1	12	44.4	9	47.4
	From 10 to 20 student research topics	4	11.8	3	11.1	3	15.8
	More than 20 student research topics	7	20.6	5	18.5	5	26.3
	Other options	5	14.7	5	18.5	1	5.3
The highest result that the student supervised has achieved in scientific research	Student Research Topics Winning School/University Level Awards	8	23.5	7	25.9	6	31.6
	Student Research Topics Winning City/ Provincial Level Awards	5	14.7	3	11.1	4	21.1
	Student Research Topics Winning National/ International Level Awards	3	8.8	2	7.4	3	15.8

In terms of academic qualifications, 23 participants (65.7%) held a Ph.D. (including 9 Associate Professors (26.5%) and 1 Professor); 10 participants (29.4%) held a master's degree or were currently Ph.D. candidates, and only 1 participant had a Bachelor's degree. Regarding their tenure in the education sector, half of the participants had 15 years or more of experience, 12 participants (35.3%) had 10 to 15 years of experience, and the remaining participants had less than ten years of experience.

All participants had experience in teaching, researching, and supervising pedagogical students in ESR. This is a crucial requirement because, according to the Delphi method, participants must be experts in the research field [42]. Regarding practical experience in supervising student research, most participants had supervised fewer than ten student research projects (15 participants, 44.1%); 4 participants had supervised between 10 and 20 projects, and 7 participants (20.6%) had supervised more than 20 student research projects. The highest achievement attained by the students under their supervision in research included school/university-level awards (8/34, 23.5%); city/provincial-level awards (5/34, 14.7%); and national /international-level awards (3/34, 8.8%).

The key results from Round 1 are presented in Table 4, along with the medians and Quartile Deviation (QD). All items had QD less than 1, and 13 items had medians greater than 3.5. The items with medians less than 3.5 were "Cumulative GPA" (Item 13) and "Gender" (Item 15). The experts also recommended adjusting the terminology of three items (Items 4, 9, and 15) and adding six items (Items 15–21) for inclusion in the next round of research.

Table 4. Delphi study results after three rounds

No	Factor	Round 1 (n = 34)		Round 2 (n = 27)			Round 3 (n = 19)			Result
		Mean	QD	Mean	QD	Rating Variant	Mean	QD	Rating Variant	
1	Policies encouraging the use of ICT in ESR	4.36	0.5	4.41	0.5	11.1%	-	-	-	Accepted in round 2
2	Financial support for using ICT in ESR	4.12	0.5	4.04	0.5	11.1%	-	-	-	Accepted in round 2
3	ICT infrastructure supporting ESR	4.18	0.5	4.07	0.5	11.1%	-	-	-	Accepted in round 2
4	Type of school currently participating in study (single-major/multi-disciplinary) *Type of school (pedagogical/ multidisciplinary)**	3.67	0.5	3.44	0.5	3.7%	-	-	-	Rejected in round 2
5	Curriculum including modules on using ICT in learning and research	4.52	0.5	4.48	0.5	11.1%	-	-	-	Accepted in round 2
6	Guidance from supervisors in research activities	4.33	0.5	4.26	0.5	11.1%	-	-	-	Accepted in round 2
7	Enthusiasm of research supervisors	4.15	0.5	4.26	0.5	11.1%	-	-	-	Accepted in round 2
8	Encouragement from people around	3.61	0.5	3.93	0	11.1%	-	-	-	Accepted in round 2
9	Cooperation from peers *Cooperation and support from peers**	3.97	0	3.89	0	11.1%	-	-	-	Accepted in round 2
10	Participation in student research and teaching clubs	4.06	0.5	4.04	0.5	7.4%	-	-	-	Accepted in round 2
11	Awareness and attitude about the role and significance of using ICT in ESR *Awareness of the role and significance of using ICT in ESR**	4.33	0.5	4.30	0.5	14.8%	-	-	-	Accepted in round 2
12	Time allocated for ESR	4.27	0.5	4.26	0.5	7.4%	-	-	-	Accepted in round 2
13	Cumulative GPA	3.21	0.5	3.26	0.5	11.1%	-	-	-	Rejected in round 2
14	ICT skills	4.52	0.5	4.63	0.5	11.1%	-	-	-	Accepted in round 2
15	Gender fator *Gender**	2.39	0.5	2.63	0.5	11.1%	-	-	-	Rejected in round 2
16	Foreign language proficiency **	-	-	4.07	0.5	-	4.05	0	5.3%	Accepted in round 3
17	Self-study and self-research competency **	-	-	4.63	0.5	-	4.47	0.5	10.5%	Accepted in round 3
18	Student's major at the university **	-	-	4.15	0.5	-	4.05	0.5	0%	Accepted in round 3
19	Interest and passion for ICT **	-	-	4.11	0	-	4.11	0	10.5%	Accepted in round 3
20	Real-world professional needs **	-	-	4.04	0	-	4.00	0	5.3%	Accepted in round 3
21	Changing role of teachers in the future **	-	-	4.00	0.5	-	4.05	0	10.5%	Accepted in round 3

* Items have been adjusted in terminology as proposed in Round 1; ** New items were introduced in Round 2, as proposed in Round 1.
Note: QD = quartile deviation

B. *Round 2 Survey Results*

In Round 2, the questionnaire consisted of 21 items, including 15 from Round 1 (with adjustments). These items were accompanied by information on the Round 1 interview results (mean, standard deviation, percentage of agreement) and the responses from the first round, allowing respondents to reconsider their opinions in the current round. Six additional items were included based on suggestions from Round 1: "student foreign language proficiency," "student self-learning and self-research competency," "student major at the university," "student interest and passion for ICT," "real-world professional needs," and "the changing role of teachers in the future." Respondents were asked to rate the importance of these 21 items on a 5-point scale ranging from 1 (very unimportant) to 5 (very important) and to provide comments, explanations, or suggestions for revisions of each factor (if any). Item 22 invited respondents to suggest additional factors and assign a corresponding importance rating. Instructions for completing the questionnaire were also included to ensure participants understood how to proceed.

The Delphi team sent a personalized email to all 34 individuals who participated in Round 1, inviting them to continue in Round 2. Since all respondents were active researchers who might have been too busy to check their emails for the Round 2 invitation, reminder emails/messages were sent to those who had not responded within two weeks. 27 out of 34 participants agreed to continue in Round 2. Seven experts did not continue in the study after Round 1. Dropout between rounds is natural in Delphi studies for various reasons, such as time constraints, lack of commitment, or waning interest [45]. Table 3 lists the personal characteristics of the 27 experts who agreed to continue in Round 2.

The results of Round 2 are presented in Table 4. The outcomes of Round 2 reaffirm the results from Round 1: 12 items were accepted according to the KAMET rule (all with a mean score $M_{qi} \geq 3.5$, quartile deviation $(Q_{qi}) \leq 0.5$, and a rating variant $(V_{qi}) < 15\%$). Meanwhile, 3 items (Items 4, 13, 15) had mean scores lower than 3.5, quartile deviation $(Q_{qi}) \leq 0.5$, and rating variant $(V_{qi}) \leq 15\%$, leading to their elimination and no need for expert consultation in the next round.

For the 6 new items added in Round 2 (Items 16–21), they all received relatively high average scores (ranging from 4.04 to 4.63), and the quartile deviation were all ≤ 0.5. According to the KAMET rule, these items will be included for expert consultation in Round 3

C. Round 3 Survey Results

In Round 3, the questionnaire included eight items: 6 items identified for further evaluation, 1 item asking respondents if any terminological adjustments were needed for previous items, and 1 item asking if any additional influencing factors should be considered. A total of 19 participants responded to the survey in this round. No additional factors were suggested, nor were there any requests for terminological adjustments.

The average scores for the items ranged from 4.00 to 4.47, with quartile deviation ranges from 0 to 0.5. The percentage of experts who changed their opinions ranged (Rating Variant) from 0% to 10.5%. Based on the KAMET rule, all six items were accepted, and no further survey rounds were necessary.

As a result, after three rounds of Delphi surveys, we identified 18 factors corresponding to 18 items that achieved high consensus and are considered to influence the competency of applying ICT in Educational, Scientific Research (ESR) of pedagogical students. These factors are: Policies encouraging the use of ICT in ESR, Financial support for using ICT in ESR, ICT infrastructure supporting ESR, Curriculum including modules on using ICT in learning and research, Changing role of teachers in the future, Guidance from supervisors in research activities, Enthusiasm of research supervisors, Encouragement from people around, Cooperation and support from peers, Participation in student research and teaching clubs, ICT skills, Foreign language proficiency, Self-study and self-research competency, Awareness of the role and significance of using ICT in ESR, Student's major at the university, Interest and passion for ICT, Time allocated for ESR, and Real-world professional needs.

The factors that did not reach consensus among the experts were the type of school currently attended (pedagogical/ university), the cumulative GPA of the student, and the student's gender. These factors also had low consensus rates in the first round.

VI. Discussion

After three rounds of surveys using the Delphi method, this study identified 18 factors influencing the competency of applying ICT in ESR among pedagogical students, grouped into four categories: factors related to the environment and conditions for learning and scientific research, influence from surrounding people, students' competency and awareness, and students' characteristics. This study's critical novel insight is the Delphi method's comprehensive and systematic application, which is relatively underutilized in this context, providing a robust consensus-driven framework for identifying factors. Moreover, the findings revealed several patterns not widely addressed in prior research, such as the significant role of policies and financial support in motivating students' ICT adoption in research and the critical influence of passion for ICT in sustaining long-term engagement. This factor has been underexplored in previous studies. This study, therefore, not only extends existing research by confirming known factors but also challenges previous assumptions that institutional type (e.g., specialized ICT schools) plays a role in ICT competency development. Instead, our findings suggest that individual effort and external support are more decisive.

A. Factors Related to the Environment and Conditions for Learning and Scientific Research of Pedagogical Students

This group includes five factors: policies encouraging the use of ICT in ESR; financial support for using ICT in ESR; ICT infrastructure supporting ESR; the curriculum including modules on using ICT in learning and ESR; and the changing role of teachers in the future.

Currently, students' application of ICT in ESR is not mandated, allowing students to choose whether to incorporate it into their research. However, in the context of increasingly extensive digital transformation, applying ICT is a prerequisite for enhancing the effectiveness of ESR. Ghavifekr and Rosdy (2015) emphasizes that institutional policies encouraging ICT integration play a pivotal role in fostering students' use of technology for learning and research [46]. The school's encouragement policies motivate students and establish a support mechanism. Since applying ICT in research requires time and effort, without appropriate incentives, students may lack the motivation to engage. Moreover, clear policies will raise students' awareness of ICT's importance in ESR while promoting specific activities to enhance their knowledge and skills in using ICT for research [23].

Most students today own computers or laptops and have good ICT skills, ensuring they have the essential tools for conducting ESR. However, additional financial support from the school will help improve the quality of student research. The application of ICT in research often involves using supporting software (paid or free), training costs, and learning resources [23, 28]. This implies that students need to invest time, effort, and finances. Given students' financial pressures, support from the school, organizations, and stakeholders will create more favorable conditions for applying ICT in ESR.

Pedagogical students' ESR activities often lean toward qualitative and social research, which does not require highly sophisticated ICT infrastructure. However, technical infrastructure is still essential in literature searches and practical research activities. If the school's infrastructure is inadequate, students may need to seek locations with better facilities. Especially in fields like simulation in Computer Science, weak technical infrastructure will severely hinder the implementation of programs and reduce the effectiveness of research. According to Underwood [47], a learning environment with good technical infrastructure creates favorable conditions for students to develop ICT skills and improve the quality of their research. Additionally, financial support from the university or external organizations will provide students with more resources to apply ICT in research, mainly using specialized software and participating in advanced training courses.

Research on ESR with high practical application in students' studies and professional careers often attracts significant interest. Therefore, if the use of ICT in ESR is closely linked with the development of professional competencies or practical applications, the effectiveness of the research will be significantly enhanced.

B. Factors Related to the Influence from Surrounding People

This group includes five factors: guidance from research supervisors in ESR activities, the enthusiasm of research supervisors, the encouragement and support from people around, cooperation and support from the research group, and participation in student scientific research clubs and pedagogical skills clubs.

The guidance of research supervisors plays a crucial role in shaping pedagogy students' research process. Students must search for documents, handle new situations, and synthesize data, which requires consulting resources and approaches from colleagues both domestically and internationally. Here, the ability to apply ICT becomes essential. The knowledge and experience of research supervisors can help students save time and focus on key skills and competencies, enhancing their ability to apply ICT in learning and research. The enthusiasm of supervisors can inspire students, but the outcome still depends on the student's initiative and desire to improve their research capabilities. When supervisors provide good guidance, encourage students to conduct research, and seek funding or related programs, this process is maximized, overcoming infrastructure-related challenges.

Encouragement and support from those around contribute to creating a positive, supportive environment, helping students gain more confidence and recognize the value of applying ICT in ESR. However, the role of people around is only supportive; the outcome still depends on the students' proactiveness in enhancing their research capabilities.

Learning and improving skills through peer exchange often have a significant positive impact on pedagogy students' academic outcomes. When working in groups, students can share knowledge and learn from each other, thus promoting the process of learning and applying ICT in research. Participation in student scientific research clubs and pedagogical skills clubs also provides opportunities for collaboration, sharing experiences, and accelerating learning, thereby increasing motivation and the ability to apply ICT in ESR.

Many previous studies have also emphasized the importance of guidance and support from teachers, as well as the role of the learning environment in enhancing students' ICT application capabilities. For instance, a study by O'Donnell *et al.* [48] demonstrated that guidance and support from teachers positively influence students' adoption of new technologies in research. Additionally, research by Walker and Fraser [49] showed that support from the research group and colleagues is crucial in motivating students to learn and apply technology in scientific research.

C. Factors Related to Students' Competency and Awareness

This group includes five factors: ICT skills, foreign language proficiency, self-study and research skills, awareness of the role and significance of using ICT in ESR, and passion for ICT.

When students clearly understand the role and significance of ICT in scientific research, they tend to use this tool more effectively. A good awareness of the importance of ICT motivates students to enhance their skills and encourages them to proactively seek opportunities to apply this technology in their studies and research. Teo's research [50] indicates that the perception of the usefulness of technology is a decisive factor in students' acceptance and use of ICT. The application of ICT requires students to have strong skills. Without these skills, students may become discouraged, give up, and lack the motivation to continue using this technology in their daily activities. This aligns with the conclusions of the study by Tarhini *et al.* [51], which emphasizes that technical skills are a crucial factor influencing students' acceptance of technology.

Additionally, foreign language proficiency is important in enhancing the ability to apply ICT. Students with good foreign language skills can easily access high-quality international resources, helping them quickly update new knowledge and skills. The study by Ghasemi and Hashemi [52] pointed out that the ability to read and understand foreign documents expands the scope of knowledge and enhances creativity and the application of technology in students' research. Finally, a passion for ICT is a key factor that helps students maintain their motivation for learning and research. When students are passionate about technology, they are likely to spend more time and effort improving their competencies. Shroff *et al.* [53] found that students with a passion and interest in ICT tend to achieve better results in their studies and research.

D. Factors Related to Student Characteristics

This group includes factors such as the time spent on scientific research, the student's academic major, and the real-world professional needs.

Each student has numerous activities at school, and serious dedication to scientific research is necessary for achieving good results. Acquiring ICT application skills requires students to allocate their time appropriately. If the time devoted to scientific research is limited, researchers may prioritize other tasks over improving their ICT application skills. Although students from different majors can access ICT knowledge through the Internet, each major has unique requirements and interests in applying ICT, particularly in scientific research. For example, social science students may focus on using qualitative data analysis software, while natural science students may prioritize using simulation tools or complex data analysis. The demands of actual professional careers also play an important role in motivating students to engage in scientific research, significantly when they recognize that ICT application skills can help them succeed in their future careers. ESR closely linked to practical learning or future professional work often generates significant student interest. When students realize that using ICT in ESR enhances their personal skills and can be applied in real-world jobs, they will have stronger motivation to participate in research.

E. Factors Not Selected

Among the factors eliminated through three rounds of Delphi surveys, some participants provided the following reasons for not selecting these factors:

Type of school (pedagogical/multidisciplinary): Schools with specialized training in ICT-related fields often have higher-quality ICT programs, leading to better ICT application competency among students. However, many talented and active students can independently improve their ICT skills through self-study. Although the type of school may influence learning activities and courses involving ICT, it does not significantly affect students' ICT application competency.

Cumulative GPA: The cumulative GPA does not accurately reflect students' ICT competency. Many students are proficient in ICT, but their grades in other subjects may not be high, resulting in a lower overall GPA. A student's decision not to invest in other subjects may lower their GPA, but this does not imply poor ICT application competency in ESR. This is consistent with findings from Passey *et al.* [54], who suggest that academic grades often do not capture the full range of digital skills or students' abilities to apply technology creatively and effectively. The ICT competency usually develops outside formal academic measures, where self-taught skills and extracurricular activities play a more significant role.

Gender: This factor is not important in determining the ICT application competency of pedagogical students. Regardless of gender, students can perform ESR well if they are passionate and have the conditions to do so. If enough time is spent learning in an environment with similar facilities, gender will not impact ICT application competency in ESR. Both male and female students have an equal opportunity and interest in applying ICT in ESR. This is consistent with the research results of Tondeur *et al.* [38].

VII. CONCLUSION

This study aimed to identify the factors influencing the competency of applying ICT in ESR among pedagogical students through the Delphi method. After conducting three rounds of surveys with 34 experts in educational science (round 1: 34, round 2: 27, round 3: 19), the research identified 18 factors influencing this competency among pedagogical students. These factors were categorized into four groups: environment and conditions for learning and scientific research, influence from surrounding people, students' competency and awareness, student characteristics.

Based on these findings, the study affirms that the development of ICT competency in ESR among pedagogical students depends on the student's personal efforts and the support provided by the school and the learning environment. Policies, curricula, and infrastructure need to be improved to meet the growing demands of students in the current digital transformation context. Enhancing awareness and skills and providing favorable conditions for pedagogy students in applying ICT will improve the quality of ESR while better-preparing pedagogy students for their future careers.

Despite the significant insights gained, this study has limitations. First, while valuable for expert consensus, the Delphi method is limited by the subjective nature of expert opinions. The number of participants decreased across rounds, which could affect the diversity of views. Furthermore, the study was conducted in the context of pedagogical students in Vietnam, which may limit the generalizability of the findings to other cultural or educational settings.

The unique contribution of this study lies in the focus on the competence of students to use ICT in ESR, a relatively unexplored field of current literature. By identifying key factors influencing this competence, this research provides a basis for future studies to be developed and concrete recommendations to improve the use of ICT in educational research. The combination of three theoretical frameworks, the TAM, the SLT, and the TPB, provides a solid and comprehensive understanding of how different elements interact and affect the ability of ICT in ESR.

Future research should explore the application of these findings in different educational contexts, for example, by comparing influences of various fields of study and regions. In addition, longitudinal studies can be conducted to evaluate the evolution of these factors over time as digital transformation in education continues. Exploring the long-term effects of enhancing ICT competencies on students' future careers and research capacity is also beneficial.

To effectively develop the skills in ICT within the ESR among students, educational institutions must prioritise improving digital infrastructure, creating support policies, and embedding ICT-related skills in the core curriculum. In addition, schools should promote mentoring programs where students can gain practical research experience under experienced educators' guidance. Schools can ensure that students are well prepared to address the challenges of digital transformation in education and contribute meaningfully to scientific research by providing adequate resources, training, and support.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

N.V.D.: Conceptualization, Writing—Original Draft, Editing and Methodology; T.T.: Conceptualization, Writing—Review & Editing and Methodology; N.C.T.: Validation and Supervision and Formal analysis; N.P.T.:

Writing—Original Draft, Writing - Review & Editing.; T.T.P.T.: Conceptualization, Writing—Original Draft, Writing—Review & Editing; all authors had approved the final version.

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