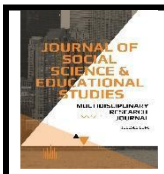

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CONSENSUS ON TECHNOLOGY INTEGRATION CONFIDENCE: A FUZZY DELPHI ANALYSIS OF TEACHER SELF-EFFICACY

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ABSTRACT

In the evolving landscape of digital education, teachers' self-efficacy in technology integration plays a pivotal role in shaping effective learning environments. This study utilizes the Fuzzy Delphi Method to identify and validate the key constructs influencing Teacher's Technology Integration Self-Efficacy, revealing significant consensus among experts. Mastery experiences, vicarious learning, verbal persuasion, and emotional responses are identified as central factors enhancing teachers' confidence. The study underscores the necessity of targeted professional development that supports these dimensions, promoting effective technological integration. Future research should investigate the longitudinal effects of such development programs and the variance in self-efficacy across different subjects.

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INTRODUCTION

In recent years, the global education landscape has undergone a significant transformation due to the digitalization of learning environments. This transition is marked by the incorporation of digital tools and resources into educational practices, a process that has been accelerated by technological advancements and greater internet accessibility (Ermakova, 2022). Countries worldwide are adopting various digital strategies to enhance learning experiences, such as incorporating online learning platforms, utilizing educational apps, and implementing virtual classrooms (Schleicher, 2020). For instance, countries like Finland, Canada, Australia, and South Korea have been at the forefront of integrating technology into their curricula, emphasizing the development of digital literacy skills among students (Kang et al., 2022). This worldwide trend signifies a broader shift towards fostering more interactive, engaging, and personalized learning experiences that equip students to meet the demands of the 21st-century workforce.

The need for technology integration in education is driven by several compelling factors. First, technology is likely to enhance the quality of education by exposing students to vast information and varied learning materials (Escueta et al., 2020). It envisions the opportunities for personalized learning that can suit the prerequisites and varying learning pace of individual students. Furthermore, the integration of technology also prepares the students to live in a digital world with the acquisition of more necessary skills, including solving problems, critical thinking, and digital literacy (Gretter & Yadav, 2016). On the other hand, technology integration greatly takes the importance of better digital infrastructure in schools with adequate digital resources. It develops awareness of the importance of technology to keep running education even when disruption is caused by the COVID-19 pandemic or similar ones soon, as reported by Dhawan (2020). These benefits show the key role that technology can play in modernizing education and improving student involvement and success.

Additionally, the push for Revolution 4.0 and the demand for technology-based learning have led to significant changes in the Malaysian educational landscape (Kolandan,2019). Teachers now need more than just technological proficiency, they also need to feel confident using these tools to engage Generation Z and Alpha learners (Hashim, 2018). Research suggests that teachers must shift their teaching strategies by focusing on modern telecommunication tools to stay relevant in the classroom. High self-efficacy among teachers enables them to implement innovative teaching methods and meet the demands of a digitalized education system (Ismail & Wahid, 2018).

Few other issues are related to the teachers' integration of technology self-efficacy, which is very important in digitizing educational transformation effectively. A major problem regarding this is the variation in teachers' confidence levels about different technologies, which acts as a barrier to their integral usage in teaching practices on a regular basis (Tondeur et al., 2017). Furthermore, inadequate professional training and development make the changes taking place in the technological tools not comprehensible for teachers to feel incompetent (Koehler & Mishra, 2009). Time is another agent impacting instructor self-efficacy because often enough they do not find an appropriate slot in their schedule for integration of technology along with the other multi-dimensional responsibilities related with teaching (Ertmer et al., 2012). Moreover, such a case may lower self-efficacy because of a feeling of being alone in such a venture; therefore, institutional support is also very important at the school leadership level (Albion, 2014). Lastly, negative experiences or technical problems have the potential to make teachers retreat from adopting new technologies; this therefore might dampen their self-efficacy (Kosov et al., 2023; Milbrath & Kinzie,2000). These are happening to be some of the influencing variables that will help in building confidence in themselves for the integration of technology. Moreover, training, both during pre-service education and throughout a teacher's career, is essential for developing self-efficacy, as it allows teachers to gain hands-on experience and reflect on their technological competence (Mannila et al., 2018). This highlights the multidimensional nature of teacher self-efficacy, where individual competence, institutional support, and leadership converge to shape successful technology integration in education.

LITERATURE REVIEW

The literature review includes the definitions of teacher's technology integration self-efficacy and the theory of self efficacy

Teacher's Technology Integration Self Efficacy

The definitions for Teacher Technology Integration Self-Efficacy are the belief of a teacher in his or her capability to use technology proficiently in the classroom (Tschannen-Moran & Hoy, 2001; Barton & Dexter, 2020). Meanwhile, Christensen and Knezek (2017) describe Teacher Technology Integration Self-Efficacy as a teacher's confidence in his or her competence to use technology. In addition, Hoy et al. (2009) consider this self-efficacy as one influencing factor in the effective use of technology in teaching by teachers. The literature on teacher self-efficacy in technology integration, as highlighted in multiple studies, provides critical insights into the factors that influence educators' confidence and effectiveness in integrating information and communication technologies (ICT) into their teaching practices. Gomez (2024) emphasizes the importance of continuous professional development aligned with ISTE Standards to improve self-efficacy among urban K-12 teachers, while Barton and Dexter (2020) advocate for a holistic approach combining formal, informal, and independent learning to enhance self-efficacy through diverse experiences. Brown (2014) underscores the need for ongoing, relevant training to boost confidence in classroom technology integration, particularly in rural settings. Meanwhile, Olayvar (2022) note that socio-demographic factors and educational frameworks influence self-efficacy, aligning with findings by Öztuzcu, Ö., and Mısırlı (2023) that prior training in technology significantly impacts confidence levels. Krause (2017) highlights the improvement of self-efficacy among pre-service physical education teachers through mastery and vicarious experiences, while a study in South Africa suggests that enhancing facilitating conditions and social influence can improve digital technology integration in science education (Jere & Mpeta, 2024). Collectively, these studies underscore the necessity of tailored professional development and supportive environments to foster effective technology integration in education. Finally, fostering a supportive school culture that encourages innovation and experimentation with technology is crucial. School leaders should promote a positive attitude towards technology integration by recognizing and rewarding teachers who successfully implement digital tools in their teaching (Teo, 2019).

Theory of Self Efficacy

The Self-Efficacy Theory of Albert Bandura is a major part of his social cognitive theory, and it looks at the beliefs that individuals can apply some sort of control on the events in their lives. People with high self-efficacy tend to approach tasks, persevere in the face of challenges, and view obstacles as opportunities for growth rather than barriers (Bandura, 1997). These beliefs are influenced by several factors: mastery experiences (successful task performance), vicarious experiences (observing someone succeed at a task), verbal persuasion (encouragement from others), and interpreting physiological responses as challenges rather than threats (Bandura, 1997). Technological integration self-efficacy in this context can be referred to as the teacher's confidence in their potential ability to integrate digital tools into teaching practice effectively. Teacher self-efficacy generally leads to increased experimentation with new technologies, modification in pedagogies, and overcoming of barriers with respect to use of technology. This innovative environment of teaching required for leveraging technology for learning can be realized only when teachers are confident about themselves (Tschannen-Moran & Hoy, 2001; Barton & Dexter, 2020).

The study aim:

This study aim is to obtain expert agreement on the constructs of Teacher's Technology Integration Self-Efficacy by using Fuzzy Delphi method.

METHODOLOGY

Participants and procedure

This study employs a Multi-Research Method approach as outlined by Richey and Klein (2007). It comprises two stages: initially, the researcher reviews relevant literature to identify the major societal impacts of hoax news. In the second stage, the Fuzzy Delphi Method (FDM) is utilized. FDM is a technique that relies on expert consensus. This method aids in determining what elements to construct by using an expert consent assessment tool to evaluate the developed structure. As the data is analyzed, a list of constructs aimed at enhancing teachers' technology integration is created through expert consensus.

Sampling procedure

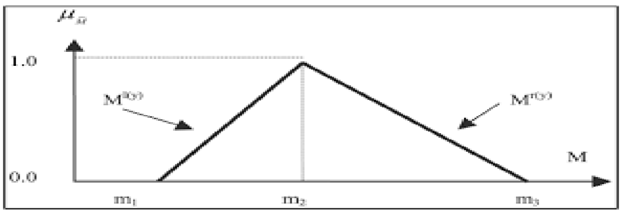
In this analysis, purposeful sampling was utilized as the primary technique. This approach is suitable because the researcher seeks to obtain expert consensus on a predefined topic. A total of 7 experts participated in the study, with their details provided in Table 1. The selection of these experts was based on their background and expertise. For Delphi studies where the experts are similar in their knowledge and experience, the recommended number of participants is between 5 and 10. However, if there is a degree of homogeneity among them, the minimum number typically ranges from 10 to 15 experts (Adler & Ziglio, 1996).

Expert criteria

According to expert criteria, Booker and McNamara (2004), experts are those who have earned their qualifications, training, experience, professional membership, and peer recognition through hard work and dedication. According to (Cantrill et al., 1996; Mullen, 2003), any person who is knowledgeable or skilled in some specific field or industry can be considered an expert. The issue of expert selection is one of the most important issues to be considered in the Fuzzy Delphi research. A poorly and vaguely selected expert selection would potentially bring into question the legitimacy, validity, and reliability of these results of the study. According to Kaynak and Macaulay (1984), the researchers who are involved in the study must represent or have knowledge regarding the topic or issue being examined. The expert is selected based on highly demanding criteria, to be one with at least seven years of experience and a right expert in their field of expertise, and in connection to the study.

Fuzzy Delphi step

Table 2 : Fuzzy Delphi Step

Step	Formulation
1. Expert selection	• The following report summarized the opinions of all 7 experts. A panel of experts was summoned for the assessment to evaluate the importance of the parameters on the factors that would be graded using linguistic variables and the definitions of potential issues with the piece, and so on.
2. Determining linguistic scale	• To complete this process, all linguistic variables are translated and represented as the number of fuzzy triangles or triangular fuzzy numbers. The inclusion of fuzzy numbers in the translation of linguistic variables is also covered in this stage. Written as (m1, m2, m3), the Triangular Fuzzy Number denotes the values m1, m2, and m3. In this case, the values denoted by m1 and m2 and m3, respectively, reflect the lowest, rational, and maximum values that are feasible. Here, linguistic variables are converted into fuzzy numbers using the Triangular Fuzzy Number to create a Fuzzy Scale.  Figure 1: Triangular fuzzy number
3. The Determination of Linguistic Variables and Average Responses	• After receiving expert opinion, researchers must transform measurement results to Fuzzy scales. This method is commonly referred to as the acknowledgement of each answer.

4. The determination of threshold value "d"	• It is evident by Thomaidis et al., (2006) that the threshold value is mainly applied for the establishment of consensus level among the experts. Using the given formula, the distances for every fuzzy integer m = (m1, m2, m3) and n = (m1, m2, m3) will be computed as: $d(\bar{m},\bar{n}) = \sqrt{\frac{1}{3}[(m1-n1)^2+(m2-n2)^2+(m3-n3)^2]}$
5. Identify the alpha cut aggregate level of fuzzy assessment	• In case of an expert consensus, one fuzzy number is assigned to each item. This approach was applied by Mustapha & Darussalam, 2017. The computation and calculation of fuzzy values could be done using the following formula: (1) 4(m1 + 2m2 + m3) Amax
6. Defuzzification process	• This approach uses the formula Amax = (1) ⁄4 (a1 + 2am + a3). When using Average Fuzzy Numbers or Average Response, the final score can range from 0 to 1 (Ridhuan et al. 2014). This technique uses three formulas: i. A = 1/3 * (m1 + m2 + m3), ii. A = 1/4 * (m1 + 2m2 + m3), and iii. A = 1/6 * (m1 + 4m2 + m3). The A-cut value is the median value between '0' and '1', with α-cut = (0 + 1)/2 = 0.5. If the resulting A value is less than the α-cut value = 0.5, the item should be rejected as it lacks expert consensus. According to Bodjanova (2006), the alpha cut value should exceed 0.50. Tang and Wu's (2010) work provides support for this statement.
7. Ranking process	• This process of positioning is done through the definition of elements based on values of defuzzification, based on the agreement of experts that the element of the highest importance is the most important place for deciding (Fortemps & Roubens, 1996).

Instrumentation

The Fuzzy Delphi research instrument was designed by the researcher based on the available related literature material. According Skulmoski et al., (2007), when developing the items for a questionnaire, there are bases such as in literature, pilot studies, and experiences. In that light, developing the questions for Fuzzy Delphi technique, they employed research literature coupled with expert interviews as well as approaches, focus group, (Mustapha & Darussalam, 2017). Another assertion that Okoli and Pawlowski have to say is that the design of items and content pieces of research should be first initiated with a survey of related literature.

As a result, the researchers used published work/literature to determine the major impact of false news on society. The following step is to generate a list of expert questions using a 7-point scale. The 7-point scale was chosen because the more scales used, the more precise and perfect the results were (Chang et al., 2011). To simplify the answer procedure for professionals, the researcher has substituted the Fuzzy value in Table 4 with a 1-7 scale value as follows:

Table 3: Fuzzy scale

Item	Fuzzy number
Strongly disagree	(0.0, 0.0, 0.1)
Disagree	(0.0, 0.1, 0.3)
Somewhat Disagree	(0.1, 0.3, 0.5)
Neutral	(0,3, 0.5, 0.7)
Somewhat agree	(0.5, 0.7, 0.9)
Agree	(0.7, 0.9, 1.0
Strongly agree	(0.9, 1.0, 1.0)

Analysis

To analyze the findings of this study, the researcher used FUDELO 1.0 software (Fuzzy Delphi Logic Software), which was specifically designed to analyze FDM data.

Data Analysis

The literature review emphasized sources of critical features of teacher's technology integration self-efficacy. With the use of Fuzzy Delphi, the researchers will further determine, by validity and consensus, whether this aspect from the experts is appropriate for inclusion in this model.

Table 4: The List of the Construct under Teacher's Technology Integration Self-Efficacy

CONSTRUCT	Descriptions
Mastery Experiences	This refers to teachers past successful experiences with technology integration.
Vicarious Experiences	This involves teachers observing their colleagues successfully integrating technology,
Verbal Persuasion	This includes encouragement and feedback from administrators, peers, or professional development trainers about teachers' ability to integrate technology
Emotional and Physiological States	This refers to teachers' emotional reactions (e.g., excitement or anxiety) when using or thinking about using technology in their teaching.
Perceived Ease of Use	Teachers' belief that the technology is easy to use and learn, which influences their willingness to integrate it into teaching
Perceived Usefulness	The belief that integrating technology will enhance teaching and student learning outcomes.
Attitude toward Technology	Teachers' general attitude toward technology, whether they see it as an asset or a hindrance in teaching
Contextual Support	The availability of institutional support, resources, and professional development for technology integration

After the researcher issues some methods that can be practiced to develop teacher's technology integration self efficacy, then the researcher forms an expert questionnaire and performs an FDM session with experts who have been selected for giving their views and then reaching a consensus. The findings are analyzed as follows:

Table 5: Fuzzy Output from FUDELO 1.0 Software

Results	Item1	Item2	Item3	Item4	Item5	Item6	Item7	Item8
Expert1	0.04949	0.0165	0.03299	0.03299	0.02474	0.02474	0.03299	0.0165
Expert2	0.00825	0.0165	0.02474	0.02474	0.02474	0.03299	0.03299	0.0165
Expert3	0.00825	0.0165	0.03299	0.03299	0.03299	0.02474	0.02474	0.0165
Expert4	0.00825	0.0165	0.02474	0.03299	0.03299	0.02474	0.02474	0.0165
Expert5	0.00825	0.0165	0.02474	0.02474	0.02474	0.02474	0.02474	0.0165
Expert6	0.00825	0.04124	0.02474	0.02474	0.02474	0.03299	0.03299	0.04124
Expert7	0.00825	0.04124	0.03299	0.02474	0.03299	0.03299	0.02474	0.04124
Statistics	**Item1**	**Item2**	**Item3**	**Item4**	**Item5**	**Item6**	**Item7**	**Item8**
Value of the item	0.01414	0.02357	0.02828	0.02828	0.02828	0.02828	0.02828	0.02357
Value of the construct								0.02533
Item < 0.2	7	7	7	7	7	7	7	7
% of item < 0.2	100%	100%	100%	100%	100%	100%	100%	100%

Average of % consensus								**100**
Defuzzification	**0.98571**	**0.97143**	**0.94286**	**0.94286**	**0.94286**	**0.95714**	**0.95714**	**0.97143**
Ranking	**1**	**2**	**4**	**4**	**4**	**3**	**3**	**2**
Status	**Accept**	**Accept**	**Accept**	**Accept**	**Accept**	**Accept**	**Accept**	**Accept**

RESEARCH FINDINGS AND DISCUSSIONS

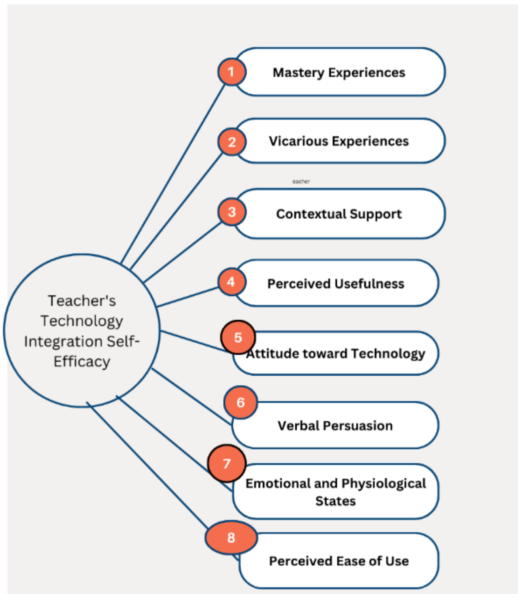
Research findings

The findings reveal that the experts reached a full consensus on all eight items, as each item's value exceeded the critical threshold of 0.2. This signifies a 100% agreement rate among the experts, with all items being deemed valid and relevant for inclusion. The values of the items range from 0.01414 to 0.02828, indicating consistency in their evaluations.

Defuzzification, which helps in ranking the items, shows that Item 1 ranks highest with a value of 0.98571, followed by Items 2 and 8 at 0.97143. Items 3, 4, and 5 share the same defuzzification value of 0.94286, placing them equally in rank. Items 6 and 7 hold a value of 0.95714, slightly higher than the others but still closely ranked.

The Fuzzy Delphi Method (FDM) applied here ensured that each item met the consensus criteria and was accepted for further use. The clear consistency across the experts' evaluations, combined with high defuzzification scores, emphasizes the robustness of these items in representing critical aspects of the teacher's technology integration self-efficacy model. All items have been accepted, showcasing a strong validation process through expert consensus.

Figure 1 : The ranking of the elements according to the experts



Discussions

The study explores the various factors influencing teachers' confidence in integrating technology into their teaching practices. Through a Fuzzy Delphi method, the analysis considers diverse expert opinions on how different constructs affect teacher self-efficacy. Key constructs, including mastery experiences, vicarious experiences, verbal persuasion, emotional and physiological states, perceived ease of use, and perceived usefulness, play a critical role in shaping teacher confidence.

Mastery experiences, derived from teachers past successful attempts at integrating technology, have been found to significantly impact their confidence levels. Similarly, vicarious experiences, where teachers observe their peers successfully integrating technology, help boost their confidence by setting positive examples. Verbal persuasion from administrators, peers, or professional development programs also plays a pivotal role by providing external validation and encouragement.

The emotional and physiological states of teachers, including feelings of excitement or anxiety, directly influence their motivation and ability to integrate technology effectively. Moreover, perceived ease of use and perceived usefulness of technology are essential; teachers who believe the technology is user-friendly and beneficial to teaching and learning are more likely to integrate it.

The study results suggest a broad consensus among experts, showing strong alignment in the perceived importance of these constructs. The defuzzification process reveals that mastery experiences and verbal persuasion are ranked highly in contributing to teacher self-efficacy, followed closely by perceived ease of use and usefulness, which align with the overarching theme of confidence building through positive reinforcement and practicality.

CONCLUSION AND RECOMMENDATION

The Fuzzy Delphi analysis of teacher self-efficacy in technology integration highlights the crucial role of past experiences, peer influence, and institutional support. Mastery and vicarious experiences, verbal persuasion, and positive emotional states emerge as dominant factors contributing to confidence. These findings underscore the importance of fostering supportive environments and practical, user-friendly technology solutions to enhance teacher efficacy in technology integration.

Future research should explore longitudinal impacts of professional development on teacher confidence in technology integration. Additionally, exploring how emerging technologies, such as artificial intelligence and virtual reality, influence teacher confidence and student outcomes would provide valuable insights for future educational practices. Research about variation in teachers' self-efficacy in technology integration across different subject matters, exploring specific challenges and successes encountered in each discipline is also encouraged.

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