Journal of Theoretical and Applied Information Technology
31st May 2025. Vol.103. No.10

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

HOW CAN EXPERT CONSENSUS METHODS ENHANCE THE DESIGN OF IMMERSIVE LEARNING PRACTICAL MODELS FOR DEAF OR HARD-OF-HEARING STUDENTS IN TVET?

RINI HAFZAH BINTI ABDUL RAHIM[1], DINNA NINA BINTI MOHD NIZAM[1], NUR FARAHA BINTI MOHD NAIM[1] and ASLINA BAHARUM[2]

[1]User Experience Group, Faculty of Computing and Informatics, University Malaysia Sabah, 88400 Kota Kinabalu, Sabah, MALAYSIA

[2] Department of Data Science and Artificial Intelligence, School of Engineering and Technology, Sunway University, Bandar Sunway, 47500 Selangor, MALAYSIA

E-mail: [1]RINI_HAFZAH_DI21@iluv.ums.edu.my, [2]dinna@ums.edu.my, [3]faraha.naim@ums.edu.my, [4]aslinab@sunway.edu.my

ABSTRACT

Traditional auditory-based teaching approaches limit the effectiveness of practical skills acquisition for Deaf or Hard-of-Hearing (DHH) students in Technical and Vocational Education and Training (TVET). Despite increased interest in immersive technologies like augmented reality (AR), the field lacks validated, inclusive instructional models tailored to DHH learners. This study addresses this gap by integrating the Nominal Group Technique (NGT) and Fuzzy Delphi Method (FDM) to design and validate an Immersive Learning Practical Skills (ILPS) model. The novelty lies in the combined use of NGT and FDM for consensus-building among experts in AR, gamification, and DHH education—an approach not commonly applied in inclusive model development. Results revealed a strong expert consensus (>97%) on 15 items across three core constructs: Learning Input Medium, Practical Skills Module, and AR Gamification Features. This research offers a replicable and participatory model development process and introduces a validated framework for inclusive immersive learning in TVET. The study contributes new knowledge by demonstrating how expert-driven methods can operationalize inclusive pedagogy through immersive technologies. This study demonstrates how combining FDM and NGT may successfully evaluate inclusive design elements for immersive learning. The results support the development of a practical skills model with a DHH focus and provide a repeatable framework for inclusive curriculum co-creation. This combination strengthen consensus among 11 panel of experts and according to the study's findings, the NGT and FDM approach has made it simple and quick for researchers to confirm crucial details that should be highlighted. To help DHH students learn more effectively, it is advised that more research be done in collaboration with course designers. To provide a scalable approach for developing immersive, accessible learning environments in specialized educational contexts, this study hopes to demonstrate how effectively NGT and FDM collaborate for inclusive instructional design.

Keywords: *Educational Technology, Teaching And Learning, Hearing Impaired, Higher Education, Model Development.*

1. INTRODUCTION

DHH students face unique challenges in acquiring practical skills due to limitations in conventional auditory-based teaching and learning methods [1]. DHH students encounter significant challenges in mastering practical skills within TVET settings due to the limitations of conventional auditory-dependent teaching methods. Despite advancements in immersive technologies such as AR and gamification, there remains a conspicuous lack of validated, inclusive instructional models that address the unique communication and learning needs of DHH learners. Furthermore, few studies have systematically applied structured expert consensus methods like the NGT and FDM to develop and validate such models. This represents a crucial methodological and pedagogical gap. Without accessible, expert-informed frameworks, DHH students risk further marginalization in skill-based learning environments. This study is needed to bridge this gap by offering a novel, validated, and replicable immersive learning model, one that leverages expert insights to ensure relevance, inclusivity, and practical effectiveness in teaching DHH learners essential technical skills.

In TVET settings, where practical skills acquisition is crucial, these challenges are especially pronounced [2–4]. The absence of adequate and inclusive instructional models often hinders DHH students from fully engaging in learning activities, impacting their skill proficiency and long-term career prospects. There is a growing need for immersive, accessible learning models that leverage cutting-edge technologies to bridge this gap, fostering an environment where DHH students can acquire practical skills more effectively [5–7].

Immersive learning techniques, particularly when combined with technology-driven approaches, hold considerable potential for improving accessibility and learning outcomes for DHH students. Techniques such as AR and gamification have been shown to enhance engagement and comprehension by creating an interactive and visually rich learning experience [8,9]. Although AR and gamification are increasingly used in educational research [10], few studies have effectively addressed the needs of DHH students, particularly in practical skill-based learning contexts. Prior works [11] and [12] have explored assistive technologies and sign language systems yet often lack a comprehensive model for immersive learning tailored to DHH learners in TVET environments. More critically, these studies generally omit structured consensus methods for model validation. The absence of participatory techniques such as the NGT and FDM undermines the rigor and inclusiveness of prior model development efforts. Addressing these gaps, the current study proposes and validates an ILPS model through a dual-method consensus approach, contributing a novel, empirically grounded framework for inclusive immersive education.

However, to design an effective immersive learning model for DHH students, it is essential to integrate input from subject matter experts and stakeholders. The NGT and FDM are particularly valuable for this purpose, enabling a systematic consensus-building process that incorporates expert opinions and prioritizes model elements according to real-world relevance and efficacy [13,14].

NGT sessions usually consist of five to ten participants and last between one and half to two hours [12,13,14]. According to Lloyd-Jones, Fowell, and Bligh (1999), the researcher's job in NGT is to facilitate and administer, which minimizes effect on the data [18]. In many research methodologies where the researcher's preconceptions are enforced through question framing and answer coding, Lomax and McLeman (1984) refer to the "omniscience of the researcher" [19]. In NGT, this is avoided since group members organize, classify, and prioritize the replies. However, the effectiveness of the approach depends on how well the stimulus question is formulated, and it is imperative that the researcher is clear about the information they hope to obtain from the procedure. In their 1975 study, Delbecq, Van de Ven, and Gustafson contrasted NGT with Fuzzy FDM [20].

The revised measurement scales are verified using a FDM. The use of fuzzy Delphi is based on the practical results of the many IT/IS research variations offered by. This tool is a very helpful method when a group of experts must accept a given level of research. Additionally, the Fuzzy Delphi procedure is an interesting method for group decision-making concerning the vague notions of expert opinion alignment [21]. In order to ensure accuracy and consistency of opinion, survey methodologies are employed in conjunction with lower expenses, which allows experts to fully express their thoughts without fear of misunderstanding and allows their results to be implemented rapidly.

The purpose of this project is to create an ILPS that is especially suited for DHH students in TVET settings. By using NGT and FDM, we want to determine the essential elements of an inclusive model, evaluate its viability, and make sure it satisfies the unique requirements of DHH students. In order to provide more equitable educational opportunities for the development of practical skills for marginalized learners, this paper examines the methodology used, the results obtained from expert inputs, and the implications of this immersive learning model on the skill acquisition of DHH students.

Given that DHH students require practical skills for effective immersive learning, our goals were to: (1) describe the characteristics of ILPS to help them learn more effectively; and (2) priorities those ILPS for intervention, keeping in mind that DHH students require practical skills for effective immersive learning. By combining NGT and FDM

Journal of Theoretical and Applied Information Technology
31st May 2025. Vol.103. No.10

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

analysis, we were able to reach a consensus of expert opinion in order to accomplish these goals.

2. LITERATURE REVIEW

Previous studies in the field of educational technology have widely documented the potential of AR and gamification to enhance learning engagement, particularly in STEM and higher education contexts [10]. Additionally, research targeting DHH students has largely centered around assistive tools such as sign language recognition systems or voice-to-visual translation platforms [11] and [12]. However, these efforts often remain isolated technological interventions without integration into a pedagogically sound or validated instructional model. More importantly, few studies have sought to develop inclusive learning frameworks specifically tailored for DHH students in TVET, where hands-on skill acquisition is paramount. Furthermore, the use of consensus-based methods such as the NGT and FDM is largely absent in prior literature, resulting in models that may lack both practical relevance and inclusivity. Motivated by these gaps, the present study introduces a validated ILPS model for DHH learners, co-developed through structured expert consensus. Unlike previous work, this study does not simply evaluate technological affordances, but contributes a scientifically grounded, scalable framework for inclusive practical skills training an innovation in both methodology and educational application.

3. METHODOLOGY

The design and development of an immersive learning model for practical skills targeted for DHH students require a rigorous and inclusive approach to ensure that the model is both effective and meets the specific learning needs of these students. This study employs a mixed-method approach, utilizing the NGT and the FDM to gather, analyze, and prioritize expert input. These methods enable a structured, consensus-driven process that incorporates diverse perspectives, facilitating the design of a learning model that is tailored to the unique requirements of DHH students in TVET contexts.

3.1 Phase 1: Identifying Key Model Components using the Nominal Group Technique (NGT)

NGT is a methodical technique that finds a group's common viewpoints on a given subject [22]. Delbecq, Van de Ven, and Gustafson described social planning scenarios as following: exploratory research; citizen engagement; use of interdisciplinary specialists; and proposal assessment [15]. Originally, it was thought of as a "participation technique for social planning situations". Since then, the method has been used in many different group contexts, including social science empirical research. Although it has been utilized in education research to some degree [23–25], it seems to be more frequently employed in the field of health studies when it comes to social science research. The NGT process is quite regimented and consists of four main stages:

1. Coming up with ideas on its own in response to a prompt.
2. Round-robin sharing (and listing) of these concepts without debate.
3. Making each concept clear on its own and assembling related concepts into groups.
4. Individuals vote to choose which ideas come first.

There is debate on the optimal sample size to employ when using NGT techniques in research. According to certain scholars, NGT may be conducted on a large group or a single cohort [19,26,27], but it can also be broken up into smaller groups to facilitate effective communication, depending on the needs of the study. Because of this, the sample sizes shown in Table 1 that have been used in previous research projects are as follows:

Table 1: NGT Sample Size [28].

Author	Sample
Van de Ven dan Delbecq (1971)	5 – 9 experts/participants
Horton (1980)	7 – 10 experts/participants
Harvey dan Holmes (2012)	6 – 12 experts/participants
Abdullah & Islam (2011)	7 – 10 experts/participants
Carney et al (1996)	Min. 6 experts/participants

Because of the aforementioned reference, the researcher chose 11 experts to take part in the

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

study's NGT and FDM method. This sum is deemed suitable for this investigation given the existing circumstances that restrict interactions.

3.2 Phase 2: Validation and Expert Consensus Using Fuzzy Delphi Method (FDM)

The procedure is broken down into a number of primary phases to finish the method. Prior to using the Delphi Fuzzy technique, the initial stage involves developing the items that require expert approval. Selecting qualified experts with backgrounds in academia and industry is the second stage. Information from chosen experts must be gathered within a specified time range for the third step. In order to generate significant correlations between the two defined outcomes, customer engagement, and the latent variable for assessment, the final stage is an analytic technique. More information about FDM steps is provided in Table 2.

Table 2: FDM Steps.

Step	Formulation
1.Expert selection	For this research, a total of eleven experts were involved. Several experts were invited in order to determine the impact of the evaluation criteria on the variables that would be investigated utilising linguistic variables. Among other things, these provide descriptions of possible issues with the item.
2.Determining linguistic scale	This method yields fuzzy triangle numbers, or triangular fuzzy numbers, from all linguistic variables. The linguistic variables are converted at this stage by adding fuzzy numbers to them [26] (m1, m2, m3) is the triangular fuzzy number, which represents the values m1, m2, and m3. m1 and m2 represent the lowest and most reasonable values, respectively, whilst m3 represent the highest values. To translate linguistic variables into fuzzy numbers, on the other hand, fuzzy scales are made using triangular fuzzy numbers. Odd digits represent the number of levels on the fuzzy scale. Figure 1 show Triangular fuzzy number.

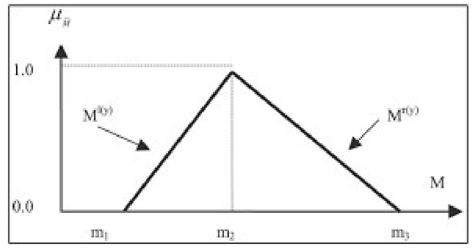

Figure 1: Triangular fuzzy number

Step	Formulation
3.The Determination of Linguistic Variables and Average Responses	Once the selected specialist responds, the researcher needs to convert all Likert scales to fuzzy scales. This process is also known as determining the average response for each fuzzy number [30].
4.The determination of threshold value "d"	When determining the degree of agreement among specialists, the threshold value is crucial [28]. The following formula is used to get the distances for each fuzzy number, m = (m1, m2, m3) and n = (m1, m2, m3):

$$d(\tilde{m},\tilde{n}) = \sqrt{\frac{1}{3}\left[(m1-n1)^2 + (m2-n2)^2 + (m3-n3)^2\right]}$$

Figure 2: Threshold value "d"

Step	Formulation
5.Identify the alpha cut aggregate level of fuzzy assessment	Each object is assigned a fuzzy number after expert consensus [32]. Fuzzy values are calculated and determined using the following formula: Amax=(1) ⁄4 (m1 + 2m2 + m3).
6.Difuzzication process	This process uses the formula Amax = (1) ⁄4 (a1 + 2am + a3). When the researcher uses average fuzzy numbers or average answers, a score number between 0 and 1 is generated [32]. A = 1/3 * (m1 + m2 + m3), A = 1/4 * (m1 + 2m2 + m3), and A = 1/6 * (m1 + 4m2 + m3) are the three formulas that are used in this operation. The median value for "0" and "1" is α-cut = (0 + 1) / 2 = 0.5; this is the A-cut value. If the resulting A value is less than the α-cut value = 0.5, the item will be rejected because this does not imply expert agreement. The alpha cut value must be more than 0.5 [33].
7.Ranking process	The placement approach selects items based on defuzzification values and

	expert agreement; the element with the highest value is determined by the most important position [34].

In order to get a high degree of expert consensus on the features that best promote the development of practical skills in DHH students, the FDM process effectively assisted in validating and refining the suggested model elements. These results show the effectiveness of FDM in inclusive design, guaranteeing that the finished model is practical and relevant especially for the target students who are DHH students.

4. RESULT

The results of this study illustrate the process and outcomes of designing an immersive learning practical skill model for DHH students in TVET. Through the NGT and FDM, a set of key elements was identified, validated, and refined to create a model that emphasizes accessibility, engagement, and practical skills acquisition. This section presents findings from each phase of the study, including expert input analysis, consensus metrics, and preliminary pilot testing outcomes with DHH students.

4.1 NGT Findings:

Table 3: Main Constructs.

Items/ Elements	Construct 1	Construct 2	Construct 3
Voter 1	6	7	7
Voter 2	7	7	7
Voter 3	6	7	7
Voter 4	7	7	6
Voter 5	7	7	7
Voter 6	7	7	6
Voter 7	7	7	7
Voter 8	6	6	6
Voter 9	7	7	6
Voter 10	6	7	7
Voter 11	7	7	7
Total Count	73	76	73
Percentage	94.81	98.7	94.81
Rank Priority	2	1	2
Total Consensus	Suitable	Suitable	Suitable

Table 4: Construct 1: DHH Learning Input Medium.

Items/ Elements	Text	Picture	Video	Sign Language
Voter 1	6	5	7	7
Voter 2	6	6	5	7
Voter 3	6	5	7	7
Voter 4	7	6	7	7
Voter 5	7	7	7	7
Voter 6	7	6	7	6
Voter 7	7	7	7	7
Voter 8	6	6	6	6
Voter 9	7	7	7	7
Voter 10	6	5	7	7
Voter 11	6	6	5	7
Total Count	71	66	62	65
Percentage	92.21	85.71	93.51	97.4
Rank Priority	3	4	2	1
Total Consensus	Suitable	Suitable	Suitable	Suitable

Table 5: Constructs 2: Practical Skills Learning Module.

Items/ Elements	Safety	Step by Step	Demonstration	Practical Skill
Voter 1	7	4	7	7
Voter 2	6	6	5	7
Voter 3	7	5	7	7
Voter 4	6	7	7	7
Voter 5	7	7	7	7
Voter 6	5	6	6	7
Voter 7	7	7	7	7
Voter 8	6	6	6	6
Voter 9	7	7	7	7
Voter 10	7	4	7	7
Voter 11	6	6	5	7
Total Count	71	65	71	76
Percentage	92.21	84.42	92.21	98.7
Rank Priority	2	3	2	1
Total Consensus	Suitable	Suitable	Suitable	Suitable

Table 6: Construct 3: AR Gamification Features.

Items/ Elements	User Interface	3D Model	Gameplay	Level Difficulty	Challenge	Reward	Score
Voter 1	5	7	6	6	6	7	5
Voter 2	6	6	7	5	6	6	7
Voter 3	6	7	7	5	6	6	6

Voter 4	7	7	6	5	7	7	7
Voter 5	6	5	6	5	4	5	7
Voter 6	6	4	6	6	7	6	6
Voter 7	7	7	7	6	6	7	7
Voter 8	6	5	5	5	5	4	5
Voter 9	7	7	7	6	5	7	7
Voter 10	6	7	6	6	6	7	5
Voter 11	6	6	7	6	6	6	7
Total Count	68	68	70	61	64	68	69
Percentage	88.31	88.31	90.91	79.22	83.12	88.31	89.61
Rank Priority	3	3	1	5	4	3	2
Total Consensus	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable

Table 3 to Table 6 displays the model's overall agreement and evaluation scores. This research shows that all model build concentrations are within the ideal range. It is now necessary for the proportion to exceed 70% in light of the results of these investigations. Every item above 70% expert consensus, according to the study of expert approval data. A few studies that bolster this idea include Mustapha et al. (2022) and Deslandes, Mendes, Pires (2010). This enables the researchers to draw the conclusion that the model's essential components are practical and well-liked by the intended audience. The lengthy rounds of expert judgement needed by the Delphi method might be replaced with a faster alternative, the modified NGT methodology [25,30,32].

4.2 FDM Findings: Validation and Consensus on Model Components

Table 7: Practical Skills Learning Module.

Defuzzification Report Result	Safety	Step by Step	Demonstration	Practical Skill
Expert 1	0.05249	0.1837	0.05249	0.02099
Expert 2	0.00525	0.04724	0.12072	0.02099
Expert 3	0.05249	0.06823	0.05249	0.02099
Expert 4	0.00525	0.10497	0.05249	0.02099
Expert 5	0.05249	0.10497	0.05249	0.02099
Expert 6	0.12072	0.04724	0.05249	0.02099
Expert 7	0.05249	0.10497	0.05249	0.02099
Expert 8	0.00525	0.04724	0.00525	0.03674
Expert 9	0.12072	0.06823	0.12072	0.15221
Expert 10	0.05249	0.1837	0.05249	0.02099
Expert 11	0.00525	0.04724	0.12072	0.02099
Statistics	Item1	Item2	Item3	Item4
Value of the item	0.04772	0.09161	0.0668	0.03435
Value of the construct	0.06012			
Item < 0.2	11	11	11	11
% of item < 0.2	100%	100%	100%	100%
Average of % consensus	100%			
Defuzzification	0.90909	0.81818	0.90909	0.96364
Ranking	2	3	2	1
Status	Accept	Accept	Accept	Accept

Table 8: DHH Student Learning Input Medium

Defuzzification Report Result	Text	Picture	Video	Sign Language
Expert 1	0.02624	0.09972	0.03674	0.0105
Expert 2	0.02624	0.01575	0.13646	0.0105
Expert 3	0.02624	0.09972	0.03674	0.0105
Expert 4	0.03149	0.01575	0.03674	0.0105
Expert 5	0.03149	0.07348	0.03674	0.0105
Expert 6	0.03149	0.01575	0.03674	0.04724
Expert 7	0.03149	0.07348	0.03674	0.0105
Expert 8	0.02624	0.01575	0.02099	0.04724
Expert 9	0.03149	0.07348	0.03674	0.0105
Expert 10	0.02624	0.09972	0.03674	0.0105
Expert 11	0.02624	0.01575	0.13646	0.0105
Statistics	Item1	Item2	Item3	Item4
Value of the item	0.02863	0.0544	0.05344	0.01718
Value of the construct	0.03841			
Item < 0.2	11	11	11	11
% of item < 0.2	100%	100%	100%	100%
Average of % consensus	100%			
Defuzzification	0.94545	0.87273	0.93636	0.98182
Ranking	2	4	3	1
Status	Accept	Accept	Accept	Accept

Table 9: Immersive Learning Augmented Reality Gamification Features

Defuzzification Report Result	User Interface	3D Model	Gameplay	Level Difficulty	Challenge	Reward	Score
Expert 1	0.12072	0.06823	0.01575	0.05249	0.03149	0.06298	0.11547
Expert 2	0.00525	0.0105	0.04199	0.06298	0.03149	0.00525	0.05774
Expert 3	0.00525	0.06823	0.04199	0.06298	0.03149	0.00525	0

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Expert 4	0.05249	0.06823	0.01575	0.06298	0.08923	0.06298	0.05774
Expert 5	0.00525	0.10497	0.01575	0.06298	0.19945	0.11022	0.05774
Expert 6	0.00525	0.22044	0.01575	0.05249	0.08923	0.00525	0
Expert 7	0.05249	0.06823	0.04199	0.05249	0.03149	0.06298	0.05774
Expert 8	0.00525	0.10497	0.13122	0.06298	0.08398	**0.22569**	0.11547
Expert 9	0.05249	0.06823	0.04199	0.05249	0.08398	0.06298	0.05774
Expert 10	0.00525	0.06823	0.01575	0.05249	0.03149	0.06298	0.11547
Expert 11	0.00525	0.0105	0.04199	0.05249	0.03149	0.00525	0.05774
Statistics	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7
Value of the item	0.02863	0.07825	0.03817	0.05726	0.0668	0.06107	0.06299
Value of the construct	0.05617						
Item < 0.2	11	10	11	11	11	10	11
% of item < 0.2	100%	90%	100%	100%	100%	90%	100%
Average of % consensus	97%						
Defuzzification	0.90909	0.88182	0.92727	0.80909	0.84545	0.89091	0.9
Ranking	2	5	1	7	6	4	3
Status	Accept	Accept	Accept	Accept	Accept	Accept	Accept

Table 7 to Table 9 show results of FDM, following data processing, the darkened threshold value is higher than the 0.2 threshold value (> 0.2) (see table 9). In other words, there are expert whose views do not accord or even coincide on some issues. The average value of all NetCollaborative Learning constructs and components, on the other hand, displays the average threshold value (d) < 0.2, or 0.08625. The item has a high degree of expert agreement if the threshold (d) average value is less than 0.2 [35,36]. In the meanwhile, the total expert agreement percentage is 100%; 100%; 97%, which is more than >75% and satisfies the requirements for expert agreement on this issue. Furthermore, the average fuzzy answer, or Alpha-Cut defuzzification values, all surpass α-cut => 0.5. The alpha cut value should be more than 0.5 and should be discarded if it is less than 0.5 [29,30,32].

5. STUDY CONTRIBUTION

Most prior research on immersive learning for DHH students has explored the use of AR or gamification individually, often without a structured approach to model development or validation. These studies rarely integrate inclusive design methodologies that systematically incorporate expert opinion across disciplines. Moreover, validation processes in earlier studies typically overlook the specific needs of DHH learners in practical skill settings, particularly within the TVET domain.

This study differs by integrating the NGT and FDM, a methodological combination not previously applied in this context to develop and validate an ILPS model. It establishes expert consensus on three core constructs (Learning Input Medium, Practical Skills Module, and AR Gamification Features), identifying 15 key elements validated with over 97% agreement. This approach not only ensures content validity but also reflects inclusive and accessible pedagogical design.

Therefore, the key contribution of this study lies in its participatory, consensus-driven development process that results in a scalable and replicable model for inclusive skill-based education for DHH students.

6. CHALLENGE AND OPEN RESEACH ISSUES

Even though this study used NGT and FDM to effectively construct and test an ILPS model for DHH students in TVET, there are still a number of obstacles and unresolved research questions.

6.1 Implementation and Usability Testing

Despite being approved by consensus of experts, the concept has not yet been put to the test in actual classroom settings. Actual learning results, learner engagement, and usability are still not quantified. Pilot studies with DHH students should be used in future studies to further hone and contextualize the model.

6.2 Learner-Centric Model Refinement

The current model is driven by experts. Although this improves content validity, DHH students themselves did not directly contribute to it. Its efficacy and inclusiveness would be improved by incorporating learner input via user experience research or participatory design.

6.3 Scalability Across Disciplines

Although the model is designed for TVET, it has not been tested for its applicability to other fields (such as science, hospitality, or automotive engineering). In order to evaluate the ILPS model's adaptability, future research might investigate domain-specific modifications.

6.4 Integration with Broader Pedagogical Frameworks

Aligning the model with well-known educational theories like Cognitive Load Theory and Universal Design for Learning (UDL) might be advantageous. To assess how the approach works with or complements these inclusive education frameworks, more research is required.

6.5 Technological Infrastructure and Teacher Readiness

Adopting immersive technology like AR needs institutional support, training, and appropriate infrastructure. Future implementation studies must address the unresolved question of whether widespread adoption in situations with limited resources is feasible.

In addition to improving the suggested ILPS paradigm, resolving these unresolved problems will further the conversation around inclusive instructional design and immersive learning tools for special education needs.

7. CONCLUSION

In conclusion, this study successfully developed and validated an ILPS model specifically designed for DHH students in TVET. The scientific contribution of this research lies in its novel integration of the NGT and FDM to systematically elicit, refine, and validate expert consensus on critical components of immersive, inclusive instructional design. This methodological innovation addresses a major gap in the literature by providing a validated model that prioritizes accessibility, engagement, and pedagogical relevance. The outcome is a scientifically grounded framework comprising 15 key elements across three validated constructs: Learning Input Medium, Practical Skills Module, and AR Gamification Features. This research not only advances the methodological rigor in inclusive education model development but also offers practical guidance for future implementations in immersive learning environments aimed at marginalized learner populations.

This study adds substantially to the existing body of knowledge by addressing a critical and underexplored area, developing validated immersive learning models for DHH students in technical and vocational education. While previous research has examined AR and gamification in general educational settings, few have targeted accessibility in model development, and none have applied the combined use of the NGT and FDM to this context. This dual-methodological approach not only enhances the rigor of model validation but also ensures inclusivity by incorporating expert consensus into every stage of design. Consequently, this study contributes a novel, empirically supported framework that can be adapted for use across inclusive educational technologies. It fills both a methodological and pedagogical gap and offers actionable insight for researchers and practitioners committed to equitable and immersive technical education.

Considering that DHH students need practical skills for successful immersion learning, this study appropriately outlines the traits of ILPS to aid in their learning and ranks those ILPS for assistance. The results show that the overall expert agreement percentage is greater than 75% and meets the criteria for expert agreement on this matter. The combined use of NGT and FDM offers a robust, efficient pathway for inclusive model validation. This approach reduces bias and ensures that educational models for DHH students are both pedagogically sound and practically validated. Future curriculum developers can adapt this method for diverse learner needs in technical education.

Using FDM instead of the traditional Delphi technique allowed this study to be finished quickly and with expert consensus, which was one of its main strengths. Furthermore, certain specialists who could have stronger opinions than others were not able to dominate the discussion due to the organized technique of NGT. This might occur, for instance, when a senior expert or focus group member has a reputation for being assertive or domineering, which influences the opinions of other experts.

This approach will undoubtedly lower the possibility of bias by guaranteeing anonymity, encouraging the experts' opinions or unconventional viewpoints, and allowing responses to be entirely independent without the fear of criticism from other participants, which is typically present in any regular group discussions or meetings. One of the method's drawbacks, though, is that the experts must be reminded repeatedly to provide their answers.

Because it improves transparency and expedites the process, using NGT and FDM together to establish expert consensus is strongly advised. The ranking of the socioecological risk variables was confirmed by the FDM analysis's

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

robustness. Therefore, it is strongly advised to include FDM in decision-making research and procedures.

While this study successfully developed and validated an immersive learning practical skills model for DHH students using expert consensus, several limitations must be acknowledged. First, the reliance on expert opinion, though rigorous via NGT and FDM, excludes direct feedback from DHH learners, limiting insights into user-centered design preferences. Second, the relatively small and context-specific expert panel may not capture broader educational diversity, affecting generalizability. Third, the model's effectiveness has not yet been empirically tested in classroom settings, meaning its pedagogical impact remains theoretical. Finally, logistical aspects such as resource availability, teacher readiness, and institutional adoption barriers were beyond the scope of this study. Recognizing these limitations not only enhances the transparency of this research but also provides a roadmap for future investigations focused on model implementation and learner outcomes.

Future research might employ other techniques by including DHH students and a more comprehensive study setting that suggests this ILPS across different fields and curricula. Based on the results of this study, future research can also create a particular module. Perhaps a specialized reference material for lecturers to use while creating and organizing their classes will be created in the future with the development of a unique immersive learning technology usage module.

REFERENCES:

[1] Halley, M. and Connelly, L., 2022. "It Made Me Think Like a Nurse": Virtual Simulations With Interpreters. Journal of Nursing Education 61(6): 334–7, Doi: 10.3928/01484834-20220404-06.

[2] Meadow-Orlans, K.P. and Sass-Lehrer, M., 1995. Support Services for Families with Children Who Are Deaf: Challenges for Professionals. Topics in Early Childhood Special Education 15(3): 314–34, Doi: 10.1177/027112149501500305.

[3] Nkolola-Wakumelo, M. and Manyando, M., 2013. A situational analysis of the use of sign language in the education of the Deaf in Zambia: A case of Magwero and St Joseph's schools for the Deaf. Language Matters 44(3): 69–88, Doi: 10.1080/10228195.2013.839733.

[4] Skelton, T. and Valentine, G., 2003. "It feels like being Deaf is normal": An exploration into the complexities of defining D/deafness and young D/deaf people's identities. Canadian Geographer 47(4): 451–66, Doi: 10.1111/j.0008-3658.2003.00035.x.

[5] Abdul Rahim, R.H., Mohd Nizam, D.N., Mohd Naim, N.F., and Baharum, A., 2024. Immersive Learning Constructs for Deaf and Hard-of-Hearing Students in TVET Practical Skill. 2024 International Visualization, Informatics and Technology Conference, IVIT 2024, Universiti Malaysia Sabah, User Experience Group, Faculty of Computing and Informatics, Sabah, Kota Kinabalu, Malaysia: Institute of Electrical and Electronics Engineers Inc. p. 192–9.

[6] Riaz, T., Anjum, A., Anjum, A., and Khan, M.A., 2023. Echoes in Silence: A Technological Leap for Pakistan Sign Language Translation and Recognition. 2023 IEEE 20th International Conference on Smart Communities: Improving Quality of Life using AI, Robotics and IoT, HONET 2023, Institute of Information Technology, Quaid-i-Azam University, Islamabad, Pakistan: Institute of Electrical and Electronics Engineers Inc. p. 204–9.

[7] Nunes, J., Verma, A., and Aruna, M., 2024. Converting Voice Signal to Visual Indian Sign Language (ISL). In: M., P., M., B., S., G.W., and K., K.A.S., editors. AIP Conference Proceedings, vol. 3075. Department of Computing Technologies, Faculty of Engineering and Technology, College of Engineering and Technology, SRM Institute of Science and Technology, Tamil Nadu, Kattankulathur, 603203, India: American Institute of Physics.

[8] El Hassan, A., Nabou, A., Jaouar, M., Ez-Zarzouri, H., Qazdar, I., and Belfarji, K., 2024. Toward a Gamified Approach Based on Augmented Resources in Education. ACM International Conference Proceeding Series, Computer Systems Engineering Laboratory (LISI), Cadi Ayyad University, Marrakech, Morocco: Association for Computing Machinery.

[9] Zhao, Y. and Wang, Q., 2024. Applying augmented reality multimedia technology to construct a platform for translation and teaching system. Heliyon 10(7), Doi: 10.1016/j.heliyon.2024.e28700.

[10] Ateş, H. and Polat, M., 2025. Leveraging augmented reality and gamification for enhanced self-regulation in science education.

[11] Leiva, V., Member, S., Zia, M., Rahman, U.R., Akbar, M.A., Castro, C., et al., 2025. A Real-Time Intelligent System Based on Machine-Learning Methods for Improving Communication in Sign Language. IEEE Access 13(February): 22055–73, Doi: 10.1109/ACCESS.2025.3529025.

[12] Pereira, A., Silva, S., Junior, O.R., José, C., Villarta, B., Rogério, M., et al., 2024. SIGN TALK ASSISTIVE TECHNOLOGY : REAL-TIME RECOGNITION OF THE LIBRAS TYPICAL ALPHABET USING ARTIFICIAL INTELLIGENCE Marcello Pereira Benevides 1 Kawan Ruiz Santiche Lima Xavier 2: 1–13.

[13] Nik Hisamuddin, R. and Tuan Hairulnizam, T.K., 2022. Developing Key Performance Indicators for Emergency Department of Teaching Hospitals: A Mixed Fuzzy Delphi and Nominal Group Technique Approach. Malaysian Journal of Medical Sciences 29(2): 114–25, Doi: 10.21315/mjms2022.29.2.11.

[14] Ahmad Zamzuri, M.I., Naserrudin, N.A., Ali, N.K.M., Aziz, S.A., Rashid, M.F.A., Dapari, R., et al., 2022. "best of Both World": The Amalgamation of Fuzzy Delphi Method with Nominal Group Technique for Dengue Risk Prioritisation Decision-Making. Journal of Function Spaces 2022, Doi: 10.1155/2022/9581367.

[15] Atherton, C.R., 1976. Group Techniques for Program Planning: A Guide to Nominal Group and dElphi Processes. by André L. Delbecq, Andrew H. Van De Ven, and David H. Gustafson. Glenview, Ill.: Scott, Foresman & Co., 1975. 174 pp. $4.75 paper. And Interpersonal Conflict Resolutio. Social Work (United States) 21(4): 338, Doi: 10.1093/sw/21.4.338.

[16] Gibson, F. and Soanes, L., 2000. The development of clinical competencies for use on a paediatric oncology nursing course using a nominal group technique. Journal of Clinical Nursing 9(3): 459–69, Doi: 10.1046/j.1365-2702.2000.00404.x.

[17] O'Neil, M.J. and Jackson, L., 1983. Nominal Group Technique: A process for initiating curriculum development in higher education. Studies in Higher Education 8(2): 129–38, Doi: 10.1080/03075078312331378994.

[18] Lloyd-Jones, G., Fowell, S., and Bligh, J.G., 1999. The use of the nominal group technique as an evaluative tool in medical undergraduate education. Medical Education 33(1): 8–13, Doi: 10.1046/j.1365-2923.1999.00288.x.

[19] Lomax, P. and McLeman, P., 1984. The Uses and Abuses of Nominal Group Technique in Polytechnic Course Evaluation. Studies in Higher Education 9(2): 183–90, Doi: 10.1080/03075078412331378834.

[20] Hsu, C.-C. and Sandford, B.A., 2007. The Delphi technique: Making sense of consensus. Practical Assessment, Research and Evaluation 12(10): 1–8.

[21] Ullah, S., Jianjun, Z., Hayat, K., Palmucci, D.N., and Durana, P., 2024. Exploring the factors for open innovation in post-COVID-19 conditions by fuzzy Delphi-ISM-MICMAC approach. European Journal of Innovation Management 27(5): 1679–703, Doi: 10.1108/EJIM-10-2022-0550.

[22] Salehi, S. and Fontana, M.E., 2024. Knowledge-based decisions for asset management of urban water infrastructure in Iran and Brazil using a nominal-based multi-criteria group decision method. International Journal of Management Science and Engineering Management, Doi: 10.1080/17509653.2024.2356154.

[23] Cooper, S., Cant, R., Luders, E., Waters, D., Henderson, A., Hood, K., et al., 2020. The nominal group technique: Generating consensus in nursing research. Journal of Nursing Education 59(2): 65–7, Doi: 10.3928/01484834-20200122-02.

[24] McCourt, C. and Thomas, B.G., 2001. Evaluation of a problem-based curriculum in midwifery. Midwifery 17(4): 323–31, Doi: 10.1054/midw.2001.0276.

[25] Gottlieb, M., Caretta-Weyer, H., Chan, T.M., and Humphrey-Murto, S., 2023. Educator's blueprint: A primer on consensus methods in medical education research. AEM Education and Training 7(4), Doi: 10.1002/aet2.10891.

[26] Muqsith Ahmad, A., Hussin, Z., Yusof Fakulti Kejuruteraan, F., Ridhuan Mohd Jamil Jabatan Kejuruteraan Mekanikal, M., and Nilai, P., 2017. Nominal Group Technique (Ngt) Dan Aplikasinya Terhadap Pembinaan Elemen Etika Dan Nilai (Akhlak) Berasaskan Aktiviti Inkuiri. Kolej Komuniti Journal of Social Sciences and Humanities 1: 128–2875.

[27] Dobbie, A., Rhodes, M., Tysinger, J.W., and Freeman, J., 2004. Using a modified nominal group technique as a curriculum evaluation tool. Family Medicine 36(6): 402–6.

[28] Mustapha, R., Ibrahim, N., Mahmud, M., Jaafar, A.B., Wan Ahmad, W.A., and Mohamad, N.H., 2022. Brainstorming the Students Mental Health after Covid-19 Outbreak and How to Curb from Islamic

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Perspectives: Nominal Group Technique Analysis Approach. International Journal of Academic Research in Business and Social Sciences 12(2): 90–9, Doi: 10.6007/ijarbss/v12-i2/12367.
[29] Hsieh, T.Y., Lu, S.T., and Tzeng, G.H., 2004. Fuzzy MCDM approach for planning and design tenders selection in public office buildings. International Journal of Project Management 22(7): 573–84, Doi: 10.1016/j.ijproman.2004.01.002.
[30] Benítez, J.M., Martín, J.C., and Román, C., 2007. Using fuzzy number for measuring quality of service in the hotel industry. Tourism Management 28(2): 544–55, Doi: 10.1016/j.tourman.2006.04.018.
[31] Thomaidis, N.S., Nikitakos, N., and Dounias, G.D., 2006. The evaluation of information technology projects: A fuzzy multicriteria decision-making approach. International Journal of Information Technology and Decision Making 5(1): 89–122, Doi: 10.1142/S0219622006001897.
[32] Jamil, M.R.M., Siraj, S., Yusof, F., Noh, N.M., Hussin, Z., and Sapar, A.A., 2015. Aplikasi Teknik Fuzzy Delphi Terhadap Keperluan Elemen Keusahawanan Bagi Pensyarah Kejuruteraan Politeknik Malaysia. International Journal of Business and Technopreneurship 5(1): 135–50.
[33] Ramlan Mustapha., Zaharah Hussin., and Saedah Siraj., 2017. Analisis faktor penyebab ketidakjujuran akademik dalam kalangan mahasiswa: Aplikasi teknik fuzzy delphi. Kurikulum & Pengajaran Asia Pasifik 5(2): 1–18.
[34] Fortemps, P. and Roubens, M., 1996. Ranking and defuzzification methods based on area compensation. Fuzzy Sets and Systems 82(3): 319–30, Doi: 10.1016/0165-0114(95)00273-1.
[35] Chang, P.L., Hsu, C.W., and Chang, P.C., 2011. Fuzzy Delphi method for evaluating hydrogen production technologies. International Journal of Hydrogen Energy 36(21): 14172–9, Doi: 10.1016/j.ijhydene.2011.05.045.
[36] Cheng, C.-H. and Lin, Y., 2002. Evaluating the Best Main Battle Tank using Fuzzy Decision Theory. European Journal of Operational Research 142: 174–86.