Journal of Human Centered Technology

https://www.humentech.utm.my E-ISSN: 2821-3467

Creating a Framework for Virtual Reality Learning Environment (VRLE) for Studio-Based Learning

Mike Choong Wai Keng[1], Maizatul Hayati Mohamad Yatim[2]*, Noorhayati Saad[2]

[1]Design School, Taylor's University, 47500 Subang Jaya, Selangor, Malaysia
[2]Faculty of Computing & Meta-Technology, Sultan Idris Education University, 35900, Tanjong Malim, Perak, Malaysia

*Corresponding Author maizatul@meta.upsi.edu.my

Cite: https://doi.org/10.11113/humentech.v3n1.64 Research Article

Abstract:
Higher education academics are lacking the knowledge on how to implement Design Thinking (DT) for transdisciplinary design studies that would produce Fourth Industrial Revolution Workforce Skills (4IRSkills), due to the sparsity in literature and implementation guidelines. This article discusses on the creation process of a Teaching and Learning Framework (TLF) for transdisciplinary design studies with a desktop-based Virtual Reality Learning Environment (VRLE) simulation of studio-based learning. The framework was created using a Selander's Learning Design Sequence (LDS) with DT approach. The LDS helped the researcher to understand the processes of teaching and learning, especially on the affordances of various modes. The DT approach was used to facilitate the process of solving problems through the practice of empathy, reframing, prototyping, experimentation, testing, and redesign. A sequential explanatory mixed method was used, and the data were analyzed through inferential statistical analysis, thematic analysis and convergent coding matrix triangulation protocol. The findings indicated that the TLF with VRLE showed a positive and significant relationship with students' achievement of 4IRSkills. The TLF Design Process and Collaborative Design variables were positively correlated with students' 4IRSkills, while there was no correlation for the VRLE Representational Fidelity and Learner Interaction variables. In conclusion, the TLF with VRLE proves to be an effective and suitable method for guiding the implementation of pedagogies that teaches 4IRSkills at the tertiary level in fully online learning environments.

Keywords: Virtual reality learning environment; Learning design sequence; Design thinking; Framework

1. INTRODUCTION

The Fourth Industrial Revolution (4IR) which fuses the physical, digital, and biological technology clusters is disrupting businesses, markets, the workforce, education and even how we live. It is a technological revolution that is transforming at a scale, scope and complexity that is unlike anything humankind has ever experienced before (1). The World Economic Forum (WEF) 'Catalysing Education 4.0' Report pointed out that the call to action for education reform needs participatory design methodologies as part of the enablers. This is supported by the WEF Education 4.0 Framework which identified innovation and creative skills as one of the eight pedagogies to pursue in achieving Education 4.0. While many universities in general, are structured to 'funnel' students down a track to become specialists and are unlikely to encourage nor reward transdisciplinary students who can work and think across disciplines, as they are often regarded as unfocused 'dabblers' (2,3). Higher education institutions need to respond to the challenges of the 4IR by advocating the transdisciplinary framework that adopts and embraces alternating perspectives and methods of knowing in the diversified global landscape (4).

In Malaysia, the 'Education Reform: The Malaysian Experience' report states that there is a need now for the melting of the disciplines and people are no longer confined into silo disciplines. Higher education needs to shift from mass production delivery model to technology-enabled innovations to deliver and tailor education for all students (5). Although the 21st Century Pedagogy has been defined by the Malaysian Ministry of Higher Education to address the complex and 'wicked' problems of 4IR, but there are gaps of related teaching and learning frameworks to implement the pedagogy (6). The preferred transdisciplinary teaching and learning framework need to facilitate the 21st century pedagogy that aligns with the WEF Education 4.0 framework for global citizenship skills, innovation and creativity skills, technology skills, interpersonal skills, personalized and self-paced learning, accessible and inclusive learning, problem-based and collaborative learning, lifelong and student-driven learning (1,5). These skills and pedagogies are the education transformants for the creation of the 4IR 21st century competencies.

Hence, due to the sparsity in literature and implementation guidelines, this article discusses a study to create a Teaching and Learning Framework (TLF) by implementing Design Thinking (DT) approach for transdisciplinary design studies for studio-based learning, that could guide facilitators and practitioners in implementing pedagogies that teaches tertiary students 4IR Workforce Skills (4IRSkills). To replicate studio-based learning in a Virtual Reality Learning

Received 03 October 2023; Accepted 27 October 2023
Available online 06 February 2024

Environment (VRLE), a browser and app-based virtual world creator called Spatial.io was introduced, along with an online virtual canvas, Miro. This setup allowed for individual student's desktop screen sharing, collaborative design development with peers using Design Thinking worksheets, support from facilitators and external experts during design review sessions. Students worked and interacted socially within the VRLE while creating digital artefacts like graphics, three-dimensional (3D) models, slide presentations and animations to meet their specific project requirements, simulating the experience of a physical design studio.

2. METHODOLOGY

A sequential explanatory mixed method was used to create a Framework for VRLE for studio-based learning. This approach provided an in-depth analysis of the research problem from the analysis of the quantitative data results and the subsequent qualitative data analysis that elaborated and explained the quantitative findings (7).

The explanatory approach was essential to provide a better understanding of the study's findings about the reasons behind the students' perception of the TLF with VRLE on their learning outcome achievements. For consolidation, the triangulation protocol based on the study by Farmer *et al.* (8) was implemented to analyze the key findings of all the quantitative and qualitative data (9). The TLF framework design consists of seven stages with several activities (Table 1).

Table 1. TLF framework design activities.

Activities	Description
Stage 1: Literature Review	Constructing the initial framework based on literature review findings.
Stage 2: VRLE Technology Feasibility Testing	Creating the teaching and learning framework and the VRLE components, testing and refinements.
Stage 3: Fuzzy Delphi Methods	Obtain expert consensus on the TLF with VRLE design, TGCR assessment mapping with 4IRSkills.
Stage 4: A Pilot Study	Face and content validity for the survey questionnaires and the semi-structured interview questions.
Stage 5: A Quasi-Experiment	Control Group (CG): Thirty projects from students without the TLF and VRLE intervention.
	Treatment Group (TG): Thirty project from students with TLF and VRLE intervention.
Stage 6: A Semi-Structured Interview	Control Group (CG): Ten participants
	Treatment Group (TG): Ten participants
Stage 7: Triangulation	Triangulation with convergent coding matrix, findings interpretation and drawing the conclusion.

2.1 Stage 1: Literature Review

In Stage 1, the initial TLF for VRLE was created based on literature review findings. The literature review on the LDS by (10) and later the customized version by Selander (11) informed the design of this research study's teaching and learning framework that embedded the DT five-stage process for transdisciplinary design studies (Figure 1). The literature review on LDS highlighted the limitations in ensuring students' learning progression from the first or primary transformation cycle to the next and the distraction of production activities that affected student's meta-reflection on the project's original aim. The DT five-stage process inclusion into the TLF, addressed the limitations of the LDS in ensuring the students' learning progression with incremental development of HOTS and the attainment of the 4IRSkills.

2.2 Stage 2: VRLE Technology Feasibility Testing

The VRLE technology and feasibility testing was conducted on selected online and cloud-based platforms to confirm the suitability for the TLF learning design and pedagogical approach. For this purpose, Miro, Spatial.io, and Google Docs were chosen as tools for VRLE technologies (Figure 2). Miro is an online collaborative whiteboard platform on the cloud that enables remote teams to work effectively together online, from brainstorming to planning and managing design development and production workflows. Spatial.io is a virtual reality platform that helps users organize virtual exhibitions, meetings, seminars, and other live events remotely. Google Docs is an online word processor used for the project management discussion and documentation. These platforms enable users to create customized spaces or galleries for the virtual immersion with drag and drop ease of use.

https://www.humentech.utm.my
https://doi.org/10.11113/humentech.v3n1.64

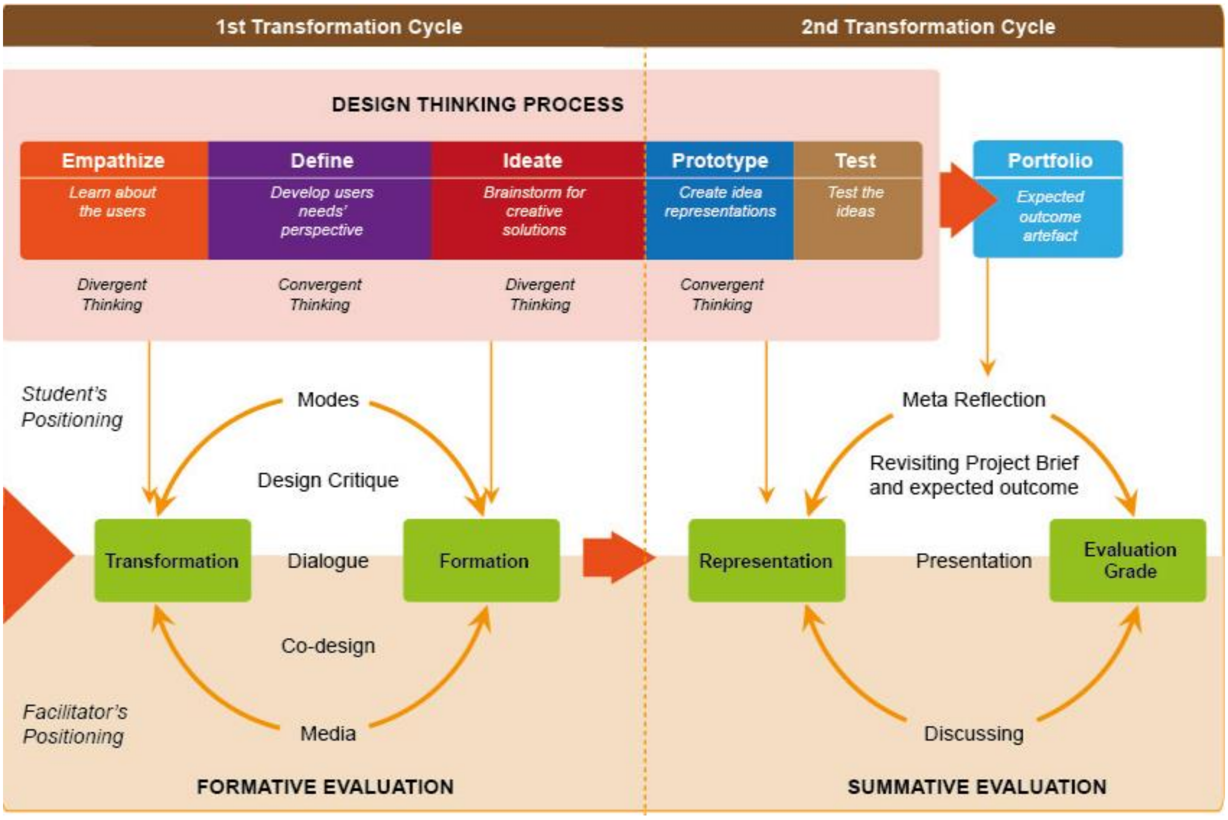
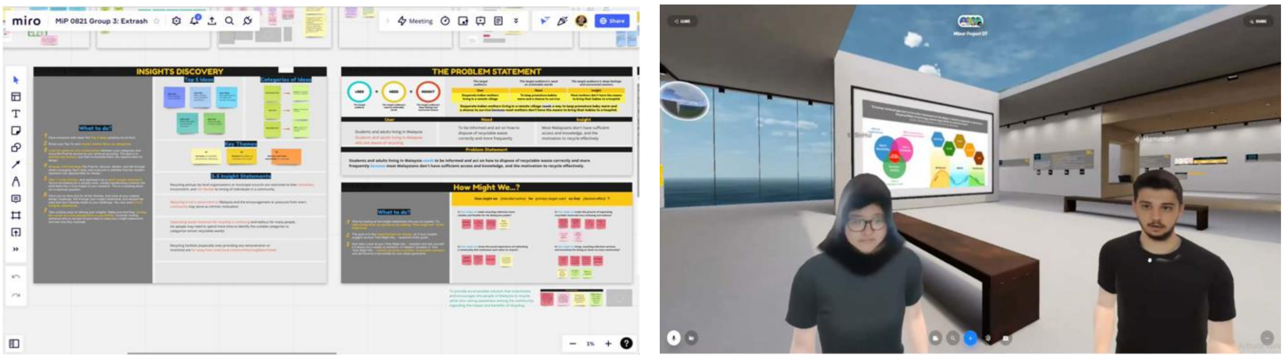


Figure 1. TLF that combines LDS and DT process.



(a) (b)

Figure 2. VRLE technologies used, consists of (a) Miro and (b) Spatial.io.

2.3 Stage 3: Fuzzy Delphi Methods

After selecting the appropriate platforms and completing the TLF design, a two-round Fuzzy Delphi Method (FDM) validation of the TLF and VRLE design with the Taylor's Graduate Capabilities Rubric (TGCR) assessment criteria mapping of the 4IRSkills was conducted. The TGCR is a rubric design for assessing a group work project (proposal – 20%), an individual project (devise and produce design management protocols – 30%), a group work project (final presentation – 40%), and an individual project (self-reflection blog – 10%). The rubric consists of four-scale: beginning, developing, mastering, and outstanding. The FDM was meant to obtain the experts' consensus before testing the TLF with VRLE, and research instruments (TGCR and interview protocol) through a pilot study.

To validate the proposed TLF and the assessment rubric, a two-round FDM iterative survey was conducted to achieve experts' consensus (12,13). The consensus was deemed as the general agreement. Any score obtained from the questionnaires and controlled opinion feedback which is higher than 75% and the defuzzification value for the items should exceed the α-cut = 0.5; was considered as a consensus (14,15). There were eight experts, purposively sampled based on their experience in virtual reality, DT and the Teaching and Learning Development fields. A total of 10 items were shared with the experts for their consent to establish the variables for the proposed TLF with VRLE; the moderating variables of gender and technical competencies; and the mapping of final assessment rubrics with 4IRSkills. The experts were expected to respond by selecting from the five-point Likert scale of Strongly Agree to Strongly Disagree variables. Added, the experts were asked to provide short supporting comments about their choice of variables. The Likert data were then translated in Fuzzy number data and analyzed using the algorithm template and triangulation steps as suggested by Rajanen and Rajanen (13). The FDM uses a Triangulation Fuzzy Number, representing the value of m1, m2, m3; which represents the minimum, reasonable and maximum values respectively. These numbers were used to produce the Fuzzy scales which are similar to the Likert scale. The threshold value d as calculated from the algorithm, should be $d \le 0.2$, to show that the experts have reached the consensus. Otherwise, a second-round will be needed to reach the consensus (16,17).

Upon reaching a consensus from the response analysis, the information was used to develop and confirm the validity of the proposed TLF and the assessment rubric before it was used for the actual quasi-experiment. The FDM required approximately four months to complete, and the experts' survey screening of the dependent variables was based on the learning outcomes of the selected module that was mapped against the identified 4IRSkills. The demographic background (moderating variable) on gender and technical competency, was also evaluated to establish the influence on the correlation between the independent and dependent variables.

The FDM functions as the expert consensus instrument to confirm on the design of the TLF with transdisciplinary design studies in VRLE studio-based learning to produce tertiary students with 4IRSkills. The FDM was also used to determine the appropriate mapping of the TGCR with the selected 4IRSkills, which was used for the students' final assessment. The TLF employed a quasi-experimental design on two different cohorts of 30 undergraduate creative media degree students each, over two different semesters; to investigate the learning effectiveness of the proposed TLF implemented in a studio-based VRLE. The correlation between the TLF and the students' attained 4IRSkills was investigated, utilizing a sequential explanatory mixed-method approach.

2.4 Stage 4: Pilot Study

A pilot study was conducted on two groups of students that shared similar demographic profiles with the actual control and treatment groups to determine the validity and reliability of the research instruments. The pilot study was conducted on a student cohort that matched the actual control group and treatment group profiles. Face and content validity for the survey questionnaire and the semi-structured interview questions were also conducted in this stage.

2.5 Stage 5: A Quasi-Experiment

A quasi-experiment was conducted in this stage. One control group (CG) was identified where the students were taught the generic online design process approach without the TLF and VRLE intervention. Specifically, students who did not experience the DT process within the TLF transformation units of signs, meaning-making, meta reflections with the formative and summative assessments. There was also no VRLE experience for the CG students as the online class was conducted on Zoom or Microsoft Teams. The data gathered from the online survey was analyzed with descriptive and inferential statistics. Concurrently, one treatment group (TG) with the TLF and VRLE experience of Design Thinking process complemented with the VRLE Spatial.io, Miro and Google Docs platforms was also being identified.

2.6 Stage 6: A Semi-Structured Interview

A semi-structured interview session on purposively selected ten students from the CG, conducted by an alternative colleague to avoid biasness and any influence between the students' assessment and the interview data's authenticity. The TG students experienced the TLF with VRLE intervention in fully online classes similar to control group G1 students but from a different cohort. This is followed by the semi-structured interview on purposively selected ten students from the TG by an alternative colleague.

2.7 Stage 7: Triangulation

The data analysis stage took place in this stage with the inferential statistics, followed by the thematic analysis of the interview transcripts and observational notes captured in the Google Docs. The final stage was the triangulation protocol with the convergent coding matrix of the quantitative and qualitative data sets for interpretations and conclusions. The triangulation method includes the convergent coding matrix, findings interpretation, and drawing the conclusion.

3. RESULTS AND DISCUSSION

This section discusses the results analyzed from the inferential statistical analysis, thematic analysis, and convergent coding matrix triangulation protocol.

3.1 Findings from the Fuzzy Delphi Method (FDM) Validation

As mentioned, the FDM was conducted in a two-round cycle by eight experts on the first round and five experts for the second round. There were ten items that were shared with the experts for the first round and the results from the eight experts did not achieve consensus for seven of the items $d \le 0.2$. A second-round FDM was conducted with five experts that have the most consensus for the items and the dependent variable components were re-matched with more appropriate TGC criteria based on the first-round's comments from the experts. The second-round FDM results showed there was consensus with all five experts where all ten items scoring $d \le 0.2$. All items from the constructs were agreed upon by all experts as all three triangulation conditions were met namely the threshold value $d \le 0.2$, the percentage of consensus above 75% and the defuzzification cut were all above the 0.5 value as shown in Table 2. The FDM results confirmed that the TLF and the final assessment rubrics are valid for the research study's quasi-experiment.

https://www.humentech.utm.my
https://doi.org/10.11113/humentech.v3n1.64

All the items from the constructs were agreed upon by all experts as all three triangulation conditions were met namely the threshold value d ≤ 0.2, the percentage of consensus above 75% and the defuzzification cut were all above the 0.5 value as shown in Table 2. The FDM results confirmed that the TLF and the final assessment rubrics are valid for the research study's quasi-experiment.

Table 2. Summary of expert consensus of construct and items for the TLF variables.

Construct (C)	%	Construct below 2.0 (d ≤ 0.2)	Item exceeding threshold (d ≤ 0.2)	Deffuzication did not reach above α-cut = 0.5
C1: Transdisciplinary Design Studies	80.0	1	-	-
C2: TLF for TDS	80.0	2	-	-
C3: VRLE TnL Model	80.0	3	-	-
C4: DT as Pedagogy	80.0	4	-	-
C5: 4IRSkills & TGCR	100.0	5	-	-
C6: Gender	80.0	6	-	-
C7: Technical Competency	100.0	7	-	-

3.2 Findings from the Pilot Study

To confirm the reliability of the research's data gathering instruments, a pilot study was conducted on two groups, namely the CG (Design Process and Design Collaboration) and the TG (VRLE Representational Fidelity and VRLE Learner Interaction). Students were selected through purposive sampling, and they were not the same as the samples for the actual quasi-experiment.

For the reliability evaluation, 30 purposively sampled students participated in the online survey questionnaires with the Design Process and Design Collaboration (CG) instruments, while twelve students answered the questionnaires with the VRLE Representational Fidelity and VRLE Learner Interaction (TG) instruments. The internal consistency results of the pilot study showed Cronbach's alpha scores that were higher than the 0.70 threshold, therefore confirming the instruments' reliability. With the reliability tests on the TLF and instruments completed and confirmed, the data analysis of the research question-based findings ensued with descriptive statistics, normality test and inferential statistical analyses. The results of the pilot study on the control group instruments showed a Cronbach's Alpha score of 0.82 and the treatment group instruments score of 0.91, which were both higher than the 0.70 threshold, which means that the instruments were reliable, and no items were removed since the internal consistency scored above 0.70.

With the validation of the TLF, the final assessment rubrics and the verification of the data gathering instruments; the actual data gathering began on both the control and treatment groups; followed by the analysis with the internal reliability determination of each instrument's scale score with Cronbach's Alpha. This was followed by the descriptive analyses (percentages, mean and standard deviation for each variable). The independent (TLF with VRLE) and dependent (4IRSkills) variables' scores were compared with the moderators (gender and technical competency). These comparisons used paired samples (dependent) t-test, independent sample t-test and one-way ANOVA, after the normality of distribution (Shapiro-Wilk) assessment was tested. Subsequently, multiple comparisons were conducted on the treatment group pre and post-test score for the effect size. The influence of the moderators (gender and technical competency), on the correlation between the independent (TLF with VRLE) and dependent (4IRSkills) variables were tested with multiple moderation analyses to review which of the moderators have greater influence in the regression. PASW (SPSS versions 25) software was used for all tests.

3.3 Findings from the Quasi-Experiment

A quasi-experiment was conducted on a control and treatment group over two different fully online academic semesters. The control group experienced a generic project design and management process while the treatment group was exposed to the TLF with VRLE. To mitigate external influences, students that were chosen for the quasi-experiment were from the same undergraduate program and academic year for both the control and treatment groups. They shared similar traits of prior knowledge and skillsets; and they are of the same age range. Other similarities included the exact number of selected students for both the control and treatment groups. Both groups experienced similar module learning outcomes and assessment criteria, and they attended full online classes throughout the same academic semester duration. This homogenous sampling and conditions were control procedures to reduce biasness or judgements.

To further control characteristic equations of the groups, pre and post-tests were implemented to analyze the student's perceptions on the variables before and after they experienced the experiment's treatment. The pre-test and post-test comparison of perceptions toward the treatment of TLF with VRLE provided a clearer understanding on actual students' perception than using the post-test measure alone. The controlled instruments for data gathering included the same sets of questionnaires for both the control and treatment groups, apart from the VRLE questions that were used only for the treatment group. The online questionnaires were distributed using the same online platform for both groups while the control procedure for the semi-structured interviews involved the assistance of an alternative colleague to conduct the interviews to remove the conflict of interest, bias and students' apprehension when commenting about their learning experience with the lecturer-researcher. Lastly, the final assessment marks were tabulated from the same set of rubrics, the TGCR for both the control and treatment groups.

A descriptive statistic test was conducted on the mean score comparison between the Control group G1 and Treatment group G2. The Control Group G1 and Treatment Group G2 final assessment marks' descriptive statistics analysis showed the mean scores of the Treatment Group G2 scoring higher (M=80.3, SD=4.04) than the Control Group G1 (M=70.7, SD=9.67). A normality test for the control and treatment group's final assessment marks was conducted and the Shapiro-Wilk test showed a significant departure from normality for both the Control group G1 and Treatment group G2, W(30)=0.83, p=0.001 and W(30)=0.87, p=0.001 respectively. The non-normality confirmation required the non-parametric Mann-Whitney U test, to determine the significant difference between the two independent groups' final marks. The Shapiro-Wilk test showed a significant departure from normality for both the Control group G1 and Treatment group G2, W(30)=0.83, p=0.001 and W(30)=0.87, p=0.001 respectively. Due to the evidence of non-normality, a non-parametric Mann-Whitney U test was conducted to determine the significant difference between the two independent groups' final marks. The inferential statistic for the control and treatment group's final assessment marks was conducted to confirm significance of the TLF with VRLE on the students' final assessment performance. There was significant difference between the Control group G1 and Treatment group G2 students' final assessment marks according to the Mann-Whitney test, U=171.0, p=0.001. This result demonstrated the evidence improved students' final assessment performance due to the applied TLF with VRLE, where the treatment group's mean score 80.3 was higher than 70.7 to the control group.

3.4 Findings from the Semi-Structured Interview

A thematic analysis was implemented based on the six steps by (18). Random sampling (n=10) was conducted on the Control group G1 and Treatment group G2 students for the semi-structured interview sessions. Each student was interviewed twice, once on the 5th week and another on the 14th week. Deductive coding was practiced with the informed data obtained from the quantitative analysis forming the theoretical lens of the mixed-method sequential explanatory approach (19, 20). The generated codes were organized into a Codebook which served as the foundation for theme generation.

The triangulation protocol with the findings were derived across the three data sets and the level of agreement in the Convergent Coding Matrix table. The findings revealed marginal agreements of 'Agreements' and 'Partial agreements' coding. No 'Disagreement' codes from the triangulation emerged but there were two 'Silence' codes found in the quantitative online survey as these two items on improved organization of design practice and increased time consumption were not tested but commented on positively in the semi-structured interviews and facilitator's observations. The other two 'silence' codes were from the students' understanding of constructive alignment as evaluated in the online survey but none of them mentioned about this alignment in the semi-structured interviews and the facilitator's observations. The final 'silence' code appeared in the semi-structured interview about the ability to monitor learning progression with online feedback, assessments, and virtual consultations, whereas students have a positive review of this item in the online survey and the facilitator's observations.

The inferential statistics indicated that students in Treatment group G2 achieved notably higher scores than those in the Control group G1. Thematic analysis revealed that this difference can be attributed to the Treatment group's understanding of the advantages of transdisciplinary collaboration, which led to the production of more comprehensive outcomes aligned with industry demands. Additionally, it bolstered students' confidence in their systematic design process. In contrast, the Control group G1 struggled with systematic design and effective collaboration. They failed to recognize the benefits of working together, lacked consensus, experienced communication problems, and had a disparity in skills among themselves. The facilitator's observations of the students' virtual learning activities highlighted several notable aspects of the Treatment group G2 students' performance. These included the demonstration of empathy and effective conflict management, a strong sense of creative confidence in problem-solving, the acquisition of new knowledge and skills and the implementation of structured and organized design practices. All of these attributes and actions were not observed in the Control group G1 students. Overall, the triangulation protocol which crossed analysed the inferential statistics, thematic analysis, and the facilitator's observations; showed marginal positive learning experience gained by the Treatment group G2 students from the TLF with VRLE, that were not evident in the Control group G1.

4. CONCLUSION

This paper briefly reports the findings for each stage in creating such framework and reflection on interpretation of quantitative results with qualitative results. Collectively, these findings confirmed the TLF with VRLE, an LDS with the embedded Design Thinking process as a viable and practical teaching and learning framework to produce 4IRSkills. The research by Wärnestål (11) was the closest attempt to implement the LDS with a user-centered process, however the research only revealed students, teachers, and client reflections of their learning experiences without evidence of mapping and measuring of the learning activities with the produced artefacts' quality to the intended learning outcomes. This inhibits the evaluation of Wärnestål's framework reliability in achieving the intended learning outcomes. Moreover, the emphasis was on user-centered design practice which focuses on individual users' usability and functionality needs rather than Design Thinking's human-centered design that provides a holistic perspective beyond technology-centered or user-centered concerns (21). Wärnestål's research provided insights on studio-based learning processes, however it is not directly applicable for creating 4IRSkills. To conclude, the paper highlighted a great need to implement future structured learning design with relevant pedagogical approaches that are suitable to produce 4IRSkills among tertiary students.

https://www.humentech.utm.my
https://doi.org/10.11113/humentech.v3n1.64

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to Taylor's University for the support and most of all appreciation to all students who enthusiastically participated and collaborated during this unprecedented time.

CONFLICT OF INTEREST

All authors have no conflict of interest.

REFERENCES

(1) Catalysing Education 4.0: Investing in the future of learning for a human-centric recovery [Internet]. 2022 [cited 2022 September 24]. Available from: https://www.weforum.org/reports/catalysing-education-4-0-investing-in-the-future-of-learning-for-a-human-centric-recovery

(2) Ward CE, Dube N, Nyambo S, Chawatama CT. A reflection on the role, potential and challenges of transdisciplinarity at the University of Fort Hare. J Transdiscipl Res S Afr. 2019; 15(1):a648. https://doi.org/10.4102/td.v15i1.648

(3) Daneshpour H, Kwegyir-Afful E. Analysing transdisciplinary education: A scoping review. Sci Educ. 2021; 31:1047–1074. https://doi.org/10.1007/s11191-021-00277-0

(4) Appel J, Kim-Appel D. Towards a transdisciplinary view: Innovations in higher education. Proceedings of Teaching and Education Conferences. 2018; 8308774.

(5) Ministry of Education. Malaysia education blueprint 2013-2025 [Internet]. Preschoool to Post Secondary Education, Putrajaya, Malaysia: Kementerian Pendidikan Malaysia. 2013 [cited 2022 September 24]. Available from: https://www.moe.gov.my/menumedia/media-cetak/penerbitan/dasar/1207-malaysia-education-blueprint-2013-2025/file

(6) Jusoh I. Mandate from Higher Education Minister [Internet]. 2018 [cited 2022 September 24] Available from: http://news.moe.gov.my/2018/01/27/2018-mandate-embracing-industry-4-0/

(7) Creswell JW. A concise introduction to mixed methods research. Thousand Oaks: SAGE Publishing; 2022.

(8) Farmer T., Robinson K, Elliott SJ, Eyles J. Developing and implementing a triangulation protocol for qualitative health research. Qual Health Res. 2006; 16(3):377–394. https://doi.org/10.1177/1049732305285708

(9) Bryman A. Social research methods. New York: Oxford University Press; 2022.

(10) Selander S. Designs of learning and the formation and transformation of knowledge in an era of globalization. Stud Philos Educ. 2008; 27(4):267–281. https://doi.org/10.1007/s11217-007-9068-9

(11) Wärnestål P. Formal learning sequences and progression in the studio: A framework for digital design education. J Inform Technol Educ: Innovations in Practice. 2016; 15(1):35–52. http://www.jite.org/documents/Vol15/JITEv15IIPp035-052Warnestal2162.pdf

(12) Gallotta B, Garza-Reyes JA, Anosike A. Using the Delphi method to verify a framework to implement sustainability initiatives. International Conference on Industrial Engineering and Operations Management (IEOM). 2018.

(13) Rajanen M, Rajanen D. Transdisciplinarity in HCI. Transdisciplinary Res Des. 2022; 5–13.

(14) Auernhammer J, Zallio M, Domingo L, Leifer L. Facets of human- centered design: The evolution of designing by, with, and for people. In: Meinel C, Leifer L, editors. Design Thinking Research. 1st ed. Springer: Cham; 2022. p. 227–245. https://doi.org/10.1007/978-3-031-09297-8_12

(15) Tangahu W, Rahmat A, Husain R. Modern education in revolution 4.0. Int J Innov Eng Res Technol, 8(1). 2021; 1–5. Retrieved from https://repo.ijiert.org/index.php/ijiert/article/view/2

(16) Chung HQ, Chen V, Olson CB. The impact of self-assessment, planning and goal setting, and reflection before and after revision on student self-efficacy and writing performance. Read Writ. 2021; 34(7):1885–1913. https://doi.org/10.1007/s11145-021-10186-x

(17) Cohen J. Statistical power analysis. Curr Dir Psychol Sci. 1992; 1(3):98-101. https://doi.org/10.1111/1467-8721.ep10768783

(18) Braun V, Clarke V. One size fits all? What counts as quality practice in (reflexive) thematic analysis?. Qual Res Psychol. 2021; 18(3):328–352. https://doi.org/10.1080/14780887.2020.1769238

(19) Murayama K, Usami S, Sakaki M. A simple and easy method for power analysis in mixed-effects modelling with nested data: Just a T-value often suffices [Internet]. 2020 [cited 2022 September 24]. Available from: https://doi.org/10.31219/osf.io/6cer3.

(20) Farmer T, Robinson K, Elliott SJ, Eyles J. Developing and implementing a triangulation protocol for qualitative health research. Qual Health Res. 2006; 16(3):377–394. https://doi.org/10.1177/1049732305285708

(21) Holeman I., Kane D. Human-centered design for global health equity. Inf Technol Dev. 2020; 26(3):477-505. https://doi.org/10.1080/02681102.2019.1667289