An Exploration Towards Sustainable Metaverse Systems for e-Learning by Student Designers: A Meta-analysis

Chien-Sing Lee[1,2,3](✉)

[1] School of Engineering and Technology, Sunway University, Subang Jaya, Malaysia
chiensingl@sunway.edu.my, csleester@gmail.com
[2] Universiti Tunku Abdul Rahman, Petaling Jaya, Malaysia
[3] Malaysian Invention and Design Society, Petaling Jaya, Malaysia

Abstract. The metaverse has caught the imagination and investments of many. However, in developing countries, the metaverse may raise more questions, than answers. As such, this study aims to investigate first, student-designers' perceptions towards what and how they want the metaverse to be like, and whether students would prioritize information flow; second, the efficacy of triangulating 3 usability-HCI questionnaires; third, whether student-designers would be more interested, creative, and be more confident in designing and developing for interconnecting (non) metaverse (eco)systems. Findings from alpha-beta user testings of Figma prototypes indicate preference for balance between structure and freedom/creativity, enhanced by user feedback and open ecosystems. Mind maps, sequencing of chain of effects in descending order, and the derived hierarchical relationship reflect centralities in design, and continuums in notions of what sustainable interconnected systems in the metaverse may be like. They are influenced by how perspectives, objectives, utility functions, and evaluation criteria, dynamically affect shifts in these centrality of design (dy/dx) over time (dy/dt), based on demographics. Loosely coupled pointer-based systems, are thus viable complements to integration.

Keywords: Interest · Student designers · Information theory · Flow · Design thinking · Computational thinking · Metaverse · Complementary interconnected ecosystems · Future knowledge management · Recommender

1 Introduction

Artificial Intelligence (AI) simulates human intelligence. Four types of AI systems have evidenced much growth in popularity: a) classifier systems, e.g. to classify whether texts from social media are positive or negative; b) recommender systems, e.g. Scratch 3.0's surprise or Lazada's interest-based recommendations; c) predictive systems, e.g. observation of data (non)random to formulate patterns, and predictions, or to integrate data from (co)curricula with curricula to predict student's performance; d) generative systems, which assemble/transform based on given parameters or metrics.

Arising partly from challenging saturated markets, the metaverse is a new frontier and testbed for AI. Zuckerberg [1] envisions the metaverse, as interconnected, loosely

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coupled ubiquitous (eco) systems, rather than tightly coupled giant integrated enterprise resource planning systems. Similarly, [2] views the metaverse as a culmination/epitome of atomistic building blocks. It interconnects socially, emotionally and cognitively, with other dimensions/worlds. Hence, what, how and the need for or the degree of integration in an interconnected universe with diverse technologies, is of interest.

[3] point out that emerging technologies, can be viewed from four quadrants. The top-bottom quadrants are augmentation and simulation, and the left-right quadrants are external and intimate. Augmentation focuses on the interface (e.g. Augmented Reality/ Virtual Reality) and interconnecting objects/networks/worlds. Simulation builds virtual models and can be (non)immersive (e.g. *SecondLife*, metaverse). External (sensors, everyware), bridges virtual-real worlds. Intimate is more personal, e.g. lifelogging/personalization; resulting in increased socio-cultural research on identity.

1.1 Problems and Objectives

With a looming global recession, we need to figure out how the real world and the metaverse, can co-exist, with different lenses. Internationally, companies e.g. JP Morgan, McDonald's, Disney, Hyundai, Gucci and Nike, have ventured into the metaverse, e.g. Decentraland and Sandbox [4]. Most sell non-fungible tokens (NFTs) and virtual experiences, e.g. games and concerts. [4] adds that in Malaysia, companies, are either selling NFTs to members of their community, which then enables access to exclusive experiences and merchandise, or are encouraging customers to virtually explore, order products, and earn points by playing games.

However, popular successful examples, e.g. Lazada and Shoppee's innovative design thinking business model, planning, and flexible/agile architecture and processes, with optional user feedback and reviews after each purchase-delivery, indicate that the notion of interconnected systems, may not require heavy investments in technologies.

So, how can the metaverse and other worlds co-exist? In line with Zuckerberg's [1] vision, an analogical parallel [5] may provide insights. In the database world, should we design based on the more structured SQL vs. the pointer-based NoSQL, or based on SQL-noSQL [6]? What is necessary in the developing world?

Problem 1: Well-formulated AI considers context, goals, tasks and evaluation, in order to proceed as planned, or to recalibrate/refine. Given the broad but fuzzy evolutions in trends, if we are to venture into the metaverse, how would they want to interact with the metaverse? What are the requirements?

Objective 1: Based on design thinking, we need to investigate students' and users' perceptions towards what they would want the metaverse to be like, and how they would want to interact with the metaverse.

Second, [7] has emphasized that above and beyond coding, we need to teach and empower children to think; to equip them for "a greater and more articulate mastery of the world," (knowledge and communicative clarity) with "a sense of the

power of applied knowledge," (application, translation and transformation of knowledge) and "a self-confidently realistic image of themselves as intellectual agents" (self-efficacy/becoming). Confucius aptly puts it as teaching a person to fish, rather than giving him/her a fish.

These concepts have partly given rise to [8]'s problem-based learning meets case-based reasoning, [9]'s wide walls creative society, [10]'s adapted driving questions, [11]'s editorial on creativity scaffolds for sustainable design-development, [12]'s learning-sciences-decision support approach for 123greetings.com card design, [13]'s series of studies on developing dispositions for social innovations and design thinking-based interconnected physical-digital media among undergraduate creative industries students in Malaysia, and subsequently, [14]'s Scratch fractal study, and [15]'s digital media for open synergistic refactoring.

Regionally, the Interest-Driven Creator (IDC) theory [16] for K-12 schools is more well-known. This research also shares common concerns with [17]'s trajectories study, but is less mathematical. In this paper's spirit of loosely-connected (eco)systems, this study and the latter are (eco)systems, which point to each other, but are context-sensitive in each respective ecosystem, and at different levels of maturity.

Problem 2: Since the metaverse is relatively new in Asia, how to prepare students to develop, direct and enhance an AI/automated-augmented world, in line with [7], continuing from [11]'s editorial.

To traverse, context-goals-tasks-evaluation-adjustments direct search and retrieval, (dis)assembly, integration. [17, 18] have postulated that if we view the influence of information- and system-related characteristics on perceived ease of use, users are more likely to regard the system as relevant to their jobs. Moreover, with high output quality/better result demonstrability, perceived usefulness and technology adoption are more likely to increase.

Furthermore, if we think along [19]'s information flow as the key mediator/director in design, it may be easier to identify what are important in each subspace, reduce information dimensions, and the degree of dependencies during design in each problem-solving subspace. Thus, [20] posits that emergence and self-organization are more beneficial, in more diverse problem-solving subspaces.

Objective 2: In line with [7]'s vision, to investigate how to guide information design and structural data-driven design using information flow and usability-HCI metrics.

Weighted evaluation methods/criteria are considered to direct search/retrieval/ transformation. Furthermore, the Technology Acceptance Models (TAM) 1, 2 and 3 [18, 22, 23], have guided much of systems analysis and design, as TAM covers system factors (TAM 1), social factors (TAM 2) and human factors (TAM 3). Information design-science is implicit in TAM. Hypothetically, if student-designers regard evaluation questionnaires, e.g. Heuristic Evaluation (HE), Computer System Usability Questionnaire (CSUQ), User Experience Questionnaire (UEQ) as complementary evaluation/explanatory/ predictive instruments, they should be able to discover what information-systems analysis and

design means, and address one of the challenges of outcome-based learning, i.e., how to balance between flexibility and structure?

Objective 2a: To investigate the efficacy of triangulating usability-Human-Computer Interaction (HCI) evaluation instruments, to enhance requirements engineering, refine design interventions and interpretation of data.

Objective 2b: To investigate whether students would prioritize information flow and reduce dimensions in systems analysis and design.

Objective 2c: To investigate what student-designers and users perceive as important from usability-HCI evaluation questionnaires (HE, CSUQ, UEQ).

Objective 3: To investigate whether students would be more interested, creative, and more confident in designing and developing for interconnecting (non) metaverse (eco)systems.

2 Related Work

2.1 Technology Acceptance Models 1, 3

[18]'s comparison of the effects of 2 TAM constructs, reveals that perceived usefulness is able to explain more than 50% of the variance in behavioural intentions, over a period of 14 weeks (Table 1). Statistically, these are naturally expected, across Gaussian populations/samples. Moreover, though significantly influencing intentions, they find that perceived ease of use's effect is small, moderated mainly by experience, and partially mediated by attitude. Hence, we next refer to HCI evaluation instruments, to enrich/triangulate TAM constructs.

Table 1. [18]'s explanatory and predictiveness of TAM 1, 3

Perceived Usefulness		Perceived Ease of Use
Explaining, Predicting	TAM 3 explains between 52–67% of variance across different time periods as well as models. Experience moderates the effect of perceived ease of use on perceived usefulness	TAM 3 explains between 43–52% of variance in perceived ease of use across different points of time, and models

2.2 HCI Questionnaires

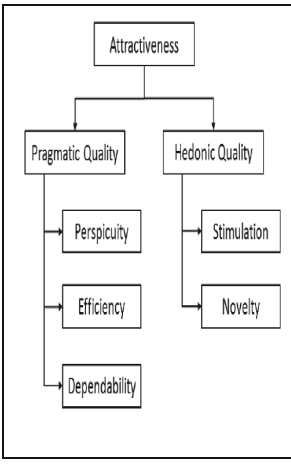
Popular usability-HCI questionnaires are [24]'s Heuristic Evaluation (HE), [25]'s Computer System Usability Questionnaire (CSUQ), and [26]'s User Experience Questionnaire (UEQ). HE provides a broad preliminary assessment of the usability of the system,

with regards to user interface design. The constructs *match with the real world*, as well as *aesthetic and minimalist design, visibility, recognition; control and freedom, flexibility and efficiency; consistency, and error prevention,* reflect common but significant user challenges. Concerned with satisfaction, CSUQ's first question assesses users' overall satisfaction with ease of use, and the final question, overall satisfaction with the system. In-between questions cover HE's constructs, weighing more on clarity and quality of interaction.

[26] extend beyond usability of the interface and system, to user experience. They have defined user experience as ultimately, about attractiveness. Often regarded as an emotional/ affective reaction, [26]'s UEQ (Table 2 right), characterizes attractiveness as comprising of two complementary qualities, i.e., pragmatic (functional/practical) and hedonic (sensorial). These states change over time, with changes in context, goals, demographics, and technologies.

Pragmatic aspects encompass goals and tasks. Contributing aspects to perceived pragmatic quality are perspicuity, efficiency and dependability. *Perspicuity* corresponds with TAM's ease of use, clarity/ease to understand and thus, ease to learn. *Efficiency* and *dependability* correspond with TAM's output demonstrability. These three aspects correspond with TAM's anchor and adjustment, influencing user confidence/control. Hedonic quality aspects are oriented towards *stimulation (*exciting, enjoyable) and *novelty.*

Table 2. UEQ (top left), HE (bottom left), CSUQ (right) with UEQ-CSUQ-HE categorizations



Clarity, Ease of use, Productivity, (Perspicuity, Efficiency, Attractiveness)	Visibility of system status
	Match between system and the real world
	User control and freedom, Flexibility and efficiency of use
	Consistency and standards, Recognition rather than recall
Error handling (Dependability)	Consistency and standards
	Recognition rather than recall
	Error prevention, Help users recognize, diagnose, recover from errors, Help and documentation
Aesthetics (Stimulation)	Match between system and the real world Aesthetic and minimalist design
Enjoyment (Stimulation)	Match between system and the real world User control and freedom, Flexibility and efficiency of use
Satisfaction (Attractiveness)	Match between system and the real world User control and freedom, Flexibility and efficiency of use Recognition rather than recall

3 Methodology

The main methodology is [27]'s multiple case study, with adaptations from [10]'s adapted spiral cascading scaffolding and adaptations from [28]. The project is part of the Human-Computer Interaction (HCI) course assignment (August 2022 semester). The course HCI,

is undertaken by the computer science, software engineering, information technology, computer networking and security and recently, the data analytics programs. Hence, balancing flexibility and structure is important. Learning is framed within the United Nations' Sustainable Development Goals (UN SDG). The inquiry-based systems analysis and design project-assignment, is divided into three parts, each simulating design thinking's iterative divergence, and convergence (Table 3).

Table 3. Assignment structure, guided mainly by CMU's systems analysis and design rubrics

Assignment Part I (problem-solving subspace 1, iteration 1)	Assignment Part II (problem-solving subspace 2, iteration 2)	Assignment Part III (problem-solving subspace 3, iteration 3)
• identify trends - Google Trends (divergence), • identify SusA's possible social, technological, environmental, economic, and individual benefits and prioritize in descending order (convergence)	• review literature, market research (divergence), • SWOT and UML (convergence)	• Design & develop (Figma), alpha-beta testing • presentation

The design challenge is based on [1]'s atomistic vision of the metaverse, which component they should connect and how, and [29]'s 7 layers. Scaffolds are Google Trends, local and global metaverse examples, SWOT, [30]'s chain of effects (simplified, with the addition of prioritization in descending order), SDLC, design patterns, adapted short version of the 2018 ACM CHI student design competition rubrics [31], and Carnegie Mellon University's (CMU) systems analysis and design rubrics [32]. Adaptations are due to cultural differences.

The 3 evaluation questionnaires are HE, CSUQ and UEQ. Since the metaverse is new to them, students choose at every stage, from the options they are given/have discovered from Google Trends and literature review, including whether to experiment with what the metaverse should be like, or to design and develop for non-metaverse systems.

4 Results and Discussion

This study is a meta-analysis. Hence, three examples of good performing student-designers' Figma prototypes (Figs. 1a, b, 3, 5) and another layer of analysis, re-representation, and interpretation to students' alpha-beta testing results are presented.

Objective of Group 1: "A one-stop solution for learners to evolve into employees, combining education, e-commerce, and a job recruitment system. The online learning system is both entertaining and educational for users, and provides users with the opportunity to connect with each other, post and seek relevant job opportunities, and purchase necessary items, in one integrated interlinked system". (extracted from students' report).

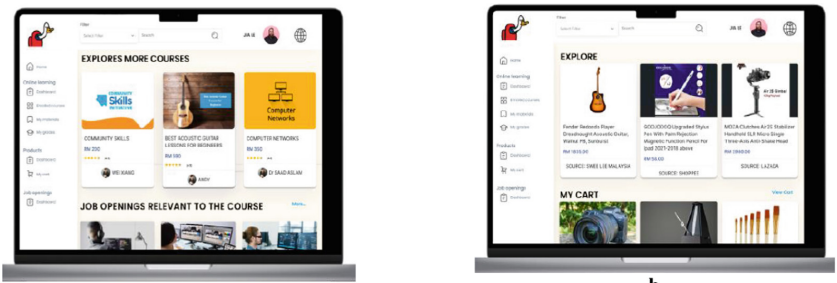
4.1 Sample

The sample respondents' brief demographics are presented in Table 4 below.

Table 4. Respondents' demographics (in %)

Age	19	20	21	22	24	25	From Sunway	Not Sunway
Alpha testing	18.8	18.8	37.5	6.3		18.8	31.3	68.8
Beta testing	23.5	17.6	11.8	41.2	5.9		58.8	41.2

Screenshots of their Figma prototype are presented in Figs. 1a and b.



a b

Figs. 1. **a** E-learning-job opportunities interconnection **b** E-learning-e-commerce interconnection.

4.2 Findings

Although given the choice of choosing 1 or 2 or 3 of the evaluation questionnaires, the first group of student-designers have chosen [23]'s HE, [24]'s CSUQ and [25]'s UEQ.

4.2.1 Alpha Testing

The HE alpha testing findings are presented in Table 5. The summation of percentages for Likert scales 6 and 7, are analyzed, as these represent the upper quartile. From Table 5, based on the summed percentages, the criteria, which score the highest are related to consistency and standards; followed by user control and freedom, flexibility and efficiency of use and aesthetic and minimalist design; and help and documentation, in third place. All criteria are pragmatic criteria, except aesthetic and minimalist design, which is a hedonistic prerequisite/consequent of pragmatic considerations.

As error prevention and system feedback have lower scores, student-designers have included buttons to text fields to prevent errors, and system feedback prompts, in beta.

Interestingly, students have compressed the CSUQ and UEQ questionnaires to only three questions, i.e., to what they really wish to know/highlight (Table 6). Students

indicate in their report that user preference for the second-ranked criteria in Table 6, makes the interlinked system design challenge sensible to them.

Table 5. HE alpha testing findings (in %) (n = 16)

No	HE evaluation criteria	Likert scale							Rank
		2	3	4	5	6	7	6 + 7	
1	Visibility of system status			18.8	25.0	31.3	25.0	56.3	
2	Match between system and real world			12.5	25.0	25.0	37.5	62.5	
3	*User control and freedom*		6.3	12.5	6.3	31.3	43.8	75.1	2
4	*Consistency and standards*			12.5	6.3	50.0	31.3	81.3	1
5	Error prevention	6.3		37.5	25.0	12.5	18.8	31.3	
6	Recognition rather than recall			25.0	12.5	43.8	18.8	62.6	
7	*Flexibility and efficiency of use*			18.8	6.3	18.8	56.3	75.1	2
8	*Aesthetic and minimalist design*	6.3		6.3	12.5	56.3	18.8	75.1	2
9	Help users recognize, diagnose, recover from errors		6.3	25.0	37.5	12.5	18.8	31.3	
10	*Help and documentation*		6.3	6.3	18.8	37.5	31.3	68.6	3

Table 6. Students' perceived significance of CSUQ-UEQ to the evaluation of their prototype, (in %) (n = 16)

No	Evaluation questions	Likert scale						Rank
	CSUQ-UEQ	3	4	5	6	7	6 + 7	
1	System has an organized and clear layout/interface (design clarity)	6.3		6.3	31.3	56.3	87.6	1
2	Users' interaction with the system with proper messages and feedback (user control, error handling, efficiency)		25.0	18.8	37.5	18.8	56.3	3
3	System has innovative, engaging design		6.3	18.8	31.3	43.8	75.1	2

The student-designers have also added a question, which is not in both CSUQ-UEQ questionnaires, i.e., whether the respondents prefer a third party for each of the subsystems (education, e-commerce, and a job recruitment system), or an integrated system. Approximately two-thirds of the respondents (68.6%) prefer an integrated system. Integration is mainly due to discovery of and easier supply chain management, convenience and data analytics. This indicates courage, self-efficacy, and deeper learning, to experiment and investigate what they really want to know (amidst the possibility of questionnaire fatigue), and more focused requirements.

4.2.2 Beta Testing

Students have made the hypothesis that "*each topic is inherently different from one another. Therefore,* a *uniform interface and structure for every subject are not viable",* but ease of use is still primary. Hence, students have the confidence to make their own assumptions, and to experiment, how to design for "innovative and engaging" interactions.

Table 7 presents the CSUQ beta testing results. To be consistent with Tables 5 and 6, ranking is based on the summed percentages of Likert scales 6 and 7, i.e., the third quartile. From Table 7, satisfaction has increased from 82.4% for ease of use, to 88.30% overall. The second highest percentage of 82.40% is equally divided between hedonistic (e.g. Q16 on pleasant interface) and pragmatic considerations (e.g. Q18 on availability of expected functions/functional usefulness, Q4, 5 on productivity). The bridge/main human factor is information clarity (e.g. Q12, 13, 14). These result in comfort in UX (e.g. Q6). Hence, there is increased importance to information flow.

Table 7. Beta testing results based on CSUQ (in %, with n = 17), alpha ranking in ()

No	CSUQ beta testing evaluation criteria	Likert scale					Rank
		4	5	6	7	6 + 7	
1	Overall, I am satisfied with how easy it is to use the system	11.8	5.9	41.2	41.2	82.4	2 (2)
2	It was simple to use this system	11.8	17.6	35.3	35.3	70.6	
3	I can effectively complete my work using this system	11.8	17.6	20.4	41.2	61.6	
4	I am able to complete my work quickly using this system	11.8	11.8	41.2	35.3	76.5	3 (3)
5	I am able to efficiently complete my work using this system	11.8	11.8	41.2	35.3	76.5	3 (3)
6	I feel *comfortable* using this system	11.8	5.9	47.1	35.3	82.4	2 (2)
7	It was easy to learn to use this system	5.9	17.6	29.4	47.1	76.5	3 (3)
8	I believe I became productive quickly using this system	17.6	5.9	41.2	35.3	76.5	3 (3)
9	The system gives error messages that clearly tell me how to fix problems	23.5	5.9	29.4	41.2	70.6	
10	Whenever I make a mistake using the system, I recover easily and quickly	17.6	17.6	29.4	35.3	64.7	
11	The information (such as online help, on-screen messages, and other documentation) provided with this system is clear	5.9	35.3	23.5	35.3	58.8	
12	It is easy to find the *information* I needed	5.9	11.8	47.1	35.3	82.4	2 (2)

(*continued*)

Table 7. (*continued*)

No	CSUQ beta testing evaluation criteria	Likert scale					Rank
		4	5	6	7	6 + 7	
13	The information provided for the system is easy to understand	5.9	17.6	35.3	41.2	76.5	3 (3)
14	The *information* is effective in helping me complete the tasks and scenarios	5.9	11.8	41.2	41.2	82.4	2 (2)
15	The organization of information on the system screens is clear	0	23.5	29.4	47.1	76.5	3 (3)
16	The interface of this system is pleasant	11.8	11.8	47.1	29.4	76.5	3 (3)
17	I like using the interface of this system	5.9	11.8	47.1	35.3	82.4	2 (2)
18	The system has all the functions and capabilities I expect	5.9	11.8	41.2	41.2	82.4	2 (2)
19	Overall, I am satisfied with this system	0	11.8	47.1	41.2	88.3	1 (1)

The questions students have chosen for UEQ for beta testing, are as short as alpha testing's. Students have decided to overcome modelling challenges, by reducing the problem-solving subspace's degree of dependencies, and dimensionality.

Clarity and feedback in Table 7 contribute to about 50% of factors ranked 2. From Table 8, UEQ's ranking corresponds with that of CSUQ's, with organized and clear interface first, followed by ease of use and creativity. Tables 7 and 8 concur with [18]'s information gain/flow. The switch between the second and third-ranking factor in beta (Table 8) compared to Table 6 (alpha), indicates that students perceive ease of use with feedback, as more important to sustainability, as feedback refines requirements gathering/design thinking.

Table 8. UEQ (results in%), with n = 17, alpha ranking in ()

No	CSUQ and UEQ evaluation criteria								Rank
		2	3	4	5	6	7	6 + **7**	
1	System is creative		11.8	5.9	23.5	17.6	41.2	58.8	3 (2)
2	System is easy to use, with feedback for improvement	5.9		11.8	17.6	23.5	41.2	64.7	2 (3)
3	System has an organized and clear layout/interface	5.9		5.9	11.8	29.4	47.1	76.5	1 (1)

Since the triangulation between HE, CSUQ and UEQ support each other, the ranking is supported. A possible hierarchical relationship among these constructs is presented in Fig. 2a. Moreover, shifts in centrality of design (dy/dx over dy/dt), involves identifying which evaluation criteria matters based on utility policies, at dy/dt, and subsequently, retrieving or pointing to the best or most suitable options. The three criteria in Fig. 2b, are examples of such evaluation criteria.

Hence, dimension reduction by identifying more significant contributing factors dynamically over time, is not necessarily promoting lossy-like compression (discard non-representative samples), but involves which variables/factors/criteria to hide, and which to activate at a certain point in time, based on the criteria and utility function at that certain point in time. Hence, integration may not always be the best solution for all. There may be a need for complements, with loosely coupled (eco)systems.

The degree of integration should be with regards to bridging certain aspects, while each retains its own unique value propositions, to freely explore opportunities for growth semi-independently, and more richly computationally, over time. Porter's (1979) five forces, i.e., competition amongst players in the industry, potential of new players in the industry, suppliers' power, customers' power and threat arising from substitute products. Ultimately, due to bounded rationality, dy/dx over dy/dt is not likely to shift much, unless the objective/utility functions, and evaluation criteria change, e.g., in trends/ cultural changes.

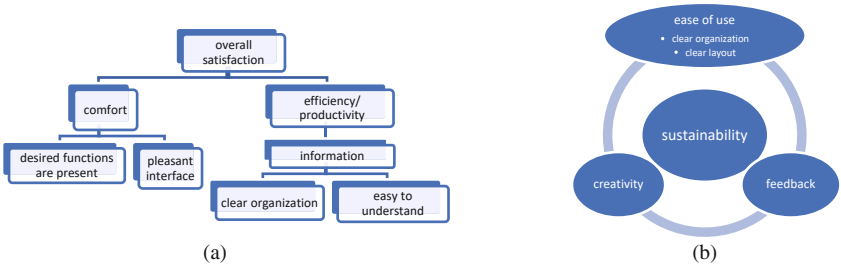


Fig. 2. Inferred hierarchy of factors contributing to overall satisfaction/attractiveness based on CSUQ (a) and highlights from CSUQ-HE-UEQ (b), with information as the bridge, and derived three key factors, as mediators and moderators, over time

4.2.3 Similarities Between Groups 1 and 2

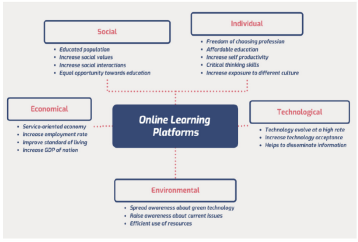
Interestingly, the two groups' prototypes, exemplify not only modular-based design, but also open/close networks/interconnections, random starting points, and episodicity. These reflect semi-structured information stacks from the back-end. Stacks are foundations/the "thread" for quantum computing.

Furthermore, similar hierarchical relationships are found in Group 2's designs (Fig. 3), but with greater emphasis on engaging and creative. Group 2's alpha testing involves respondents, who are aged between18 to 24 years old (94.9%). Most of the participants (78.4%) are Malaysians, while 21.6% are non-Malaysians. Beta testing involves respondents aged 18 to 24 years old (90.5%), and the rest, between 25–34 years old, and 35 to 44 years old. Most participants (76.2%) are Malaysians and 23.8% non-Malaysians. Student-designers' report indicate 5/5 for *match with real world, control and freedom, and error prevention* for HE, 5/5 for all UEQ criteria.

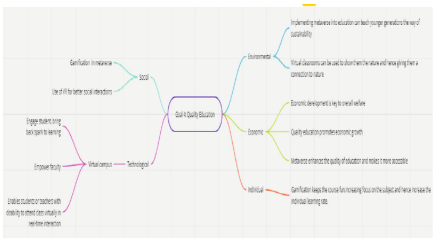
The difference lies in prioritization in the chain of effects. Group 1's report prioritizes chain of effects as individual first, followed by social, economic, technological and environmental. Possible reasons are found in their mind map (Fig. 4a). Group 2 (Fig. 4b) prioritizes social, technological, environmental, economic, individual. Both groups recognize that sustainability supports other aspects, but is hard-earned, and needs to be developed over time. Progression in students' model evolutions (alpha to beta), and complexity reduction via identifying the essence in questionnaires, indicate students have grasped what are important to their design, and how to communicate these.



Fig. 3. Similar factors in Group 2's metaverse prototype design



(a)



(b)

Fig. 4. Mind maps underlying chain of effects: Group 1's job-related centrality (a), Group 2's engagement-varied ability/age-user centrality (b)

Students' iterative subspace solutions attest to computational thinking's decomposition, algorithmic logic/information flow, [33]'s perspectives, concepts and practice, and [34]'s computer science-computational thinking, as avenue for connecting with real-world challenges. Pattern recognition is via design patterns' consistency and recognition rather than recall. Abstraction is possible with big data. Findings also support the

Learning Sciences' proposition that emergence and self-organization are more beneficial, in more diverse problem-solving subspaces and [6]'s pointer-connected information stacks, emulating LISP.

5 Comparison With E-Commerce Figma Prototype In Same Class

Students' Objective: *To explore an interlinked system and attempt to relate these systems to the metaverse. According to Google Trends, there is an increasing trend regarding e-wallet and cryptocurrency in Malaysia. Cryptocurrency is included as there are also many people interested in investing in cryptocurrency, but do not know how or where to start investing. Therefore, we decided to design a digital wallet named Cryptollar that works as an e-wallet and crypto wallet.*

5.1 Sample

The sample respondents' demographics is Gaussian, presented in Table 9.

Table 9. Sample respondents' demographics

Age	19–24	< 18, > 40	N	Male	Female
Alpha testing	91.9	8.1	37	51.4	48.6
Beta testing	91.7	5.6	36	52.8	47.2

Screenshots of the students' Figma prototype are presented in Fig. 5.



Fig. 5. Screenshots of the Cryptollar Figma prototype

5.2 Findings

The student designers have chosen HE for alpha testing, and for beta testing, HE and CSUQ. The HE results are presented in Tables 10, 11 and CSUQ in Tables 12, 13, with rankings, in the right most column. From Table 10, *user control and freedom* and *flexibility and efficiency of use* are ranked first, followed by *recognition rather than recall.* In Table y, however, there is a shift in centrality from loosely structured to more tightly structured. There is a drastic change in preference for *Visibility of system* status (unranked in alpha to rank 1 in beta) and *Consistency and standards* (ranked 5 in alpha, to rank 1 in beta) to enhance ease of use and efficiency (productivity). This is possibly due to the increased number of functions in the beta prototype, where other daily popular functions (Table 3a) are included, on top of e-wallet, crypto and NFT. Consequently, in beta, *recognition rather than recall* and *flexibility and efficiency of use* are ranked second, *user control and freedom,* fourth.

5.2.1 HE Alpha Testing

Table 10. HE alpha testing findings (in %) (n = 37)

No	HE evaluation criteria	Likert scale						Rank
		1	2	3	4	5	4 + 5	
1	Visibility of system status		2.7	29.7	40.5	27.0	67.50	
2	Match between system and the real world			24.3	43.2	32.4	75.60	3
3	***User control and freedom***			18.9	37.8	43.2	81.00	**1**
4	Consistency and standards			29.7	43.2	27.0	70.20	5
5	Error prevention		2.7	40.5	37.8	18.9	56.70	
6	*Recognition rather than recall*			21.6	59.5	18.9	78.40	2
7	***Flexibility and efficiency of use***			18.9	48.6	32.4	81.00	**1**
8	Aesthetic and minimalist design	2.7	10.8	21.6	43.2	21.6	64.80	
9	Help users recognize, diagnose, recover from errors		2.7	21.6	51.4	24.3	75.70	3
10	Help and documentation		2.7	24.3	56.8	16.2	73.00	4

5.2.2 HE Beta Testing

Table 11. HE beta testing, findings (in %) (n = 36)

No	HE evaluation criteria							Rank
		1	2	3	4	5	4 + 5	
1	***Visibility of system status***			13.9	44.4	41.7	86.1	**1**
2	Match between system and the real world		2.8	16.7	36.1	44.4	80.5	4
3	User control and freedom			19.4	47.2	33.3	80.5	4
4	***Consistency and standards***			13.9	50.0	36.1	86.1	**1**
5	Error prevention			30.6	44.4	25.0	69.4	
6	*Recognition rather than recall*			16.7	52.8	30.6	83.4	2
7	*Flexibility and efficiency of use*			16.7	30.6	52.8	83.4	2
8	Aesthetic and minimalist design			19.4	44.4	36.1	80.5	4
9	Help users recognize, diagnose, recover from errors			16.7	38.9	44.4	83.3	3
10	Help and documentation			16.7	36.1	47.2	83.3	3

5.2.3 CSUQ Alpha Findings

For alpha, overall satisfaction with ease of use is 62.1%. Overall satisfaction with the system, at 72.9%, indicates improved satisfaction of 10.8% due to other factors (Table 12). Efficiency (Q5), easy to learn (Q6), and adequate and clear information for productivity (Q14) are ranked second. Hence, the sample respondents are mainly concerned with productivity. Ease of use (Q2), easy to understand information (Q13), pleasant interface (Q16) and adequate functions (Q17) are ranked third. Hence, compared to Group 1's e-learning prototype, which has less risks, Group 3's e-wallet-crypto-NFT prototype, indicates caution due to real-time, actual financial rewards/loss.

The students have also reported that respondents' most common positive comments in CSUQ's qualitative section, are the interface is easy to navigate, and is clear. Respondents mention that the navigation method is similar to what the respondents are familiar with. The second aspect is the integration of functions commonly found in other apps, and the number of functions available in the prototype. Respondents find integrating crypto-wallet features and NFTs in one app creative.

Table 12. Alpha testing CSUQ findings (in %)

No	Evaluation criteria	Likert scale Rank							
		2	3	4	5	6	7	6 + 7	
1	Overall, I am satisfied with how easy it is to use the system			16.2	21.6	40.5	21.6	62.1	
2	It was simple to use this system			13.5	21.6	32.4	32.4	64.8	3
3	I can effectively complete my work using this system	2.7		13.5	21.6	35.1	27.0	62.1	
4	I am able to complete my work quickly using this system			13.5	27.0	35.1	24.3	59.4	
5	*I am able to efficiently complete my work using this system*			13.5	18.9	37.8	29.7	67.5	2
6	I feel comfortable using this system		2.7	16.2	24.3	35.1	21.6	56.7	
7	*It was easy to learn to use this system*	2.7	2.7	8.1	18.9	35.1	32.4	67.5	2
8	I believe I became productive quickly using this system		2.7	16.2	24.3	40.5	16.2	56.7	
9	The system gives error messages that clearly tell me how to fix problems		5.4	27.0	29.7	21.6	16.2	37.8	
10	Whenever I make a mistake using the system, I recover easily and quickly		2.7	21.6	24.3	29.7	21.6	51.3	
11	The information (such as online help, on-screen messages, and other documentation) provided with this system is clear		5.4	13.5	27.0	27.0	27.0	54.0	
12	It is easy to find the information I needed			13.5	27.0	37.8	21.6	59.4	
13	The information provided for the system is easy to understand	2.7		8.1	24.3	40.5	24.3	64.8	3
14	*The information is effective in helping me complete the tasks and scenarios*			13.5	18.9	48.6	18.9	67.5	2
15	The organization of information on the system screens is clear		2.7	16.2	18.9	37.8	24.3	62.1	
16	The interface of this system is pleasant		5.4	16.2	13.5	43.2	21.6	64.8	3
17	I like using the interface of this system		5.4	18.9	16.2	35.1	24.3	59.4	
18	This system has all the functions and capabilities I expect it to have			13.5	21.6	32.4	32.4	64.8	3
19	Overall, I am satisfied with this system			16.2	10.8	45.9	27.0	72.9	1

5.2.4 CSUQ Beta Testing Findings

The positive feedback that student-designers have received is that the users are happy with the interface (Q6), the added new features (Q13), and the colour scheme. For alpha

and beta testing, overall satisfaction with the system is ranked first. Second (Q6, Q12) and third-ranked (Q13) criteria are related to information (Table 13). Another similarity is the increase of about 10% between Q1 and Q19 in the alpha and beta CSUQ findings, and 7.6% increase between Q19 of alpha and beta. The similarity reflects the degree of variance to which CSUQ enriches HE, in approximating the percentage of contribution by non-ease-of-use factors more specifically.

Table 13. Beta testing CSUQ findings (in %)

No	Questionnaire's evaluation criteria	Likert scale Rank					
		4	5	6	7	6 + 7	
1	Overall, I am satisfied with how easy it is to use the system	11.1	27.8	22.2	38.9	61.1	
2	It was simple to use this system	8.3	22.2	30.6	38.9	69.5	4
3	I can effectively complete my work using this system	8.3	27.8	19.4	44.4	63.8	
4	I am able to complete my work quickly using this system	11.1	30.6	19.4	38.9	58.3	
5	I am able to efficiently complete my work using this system	8.3	33.3	19.4	38.9	58.3	
6	*I feel comfortable using this system*	8.3	13.9	36.1	41.7	77.8	2
7	It was easy to learn to use this system	8.3	25.0	27.8	38.9	66.7	
8	I believe I became productive quickly using this system	5.6	27.8	27.8	38.9	66.7	
9	The system gives error messages that clearly tell me how to fix problems	13.9	36.1	11.1	36.1	47.2	
10	Whenever I make a mistake using the system, I recover easily and quickly	13.9	27.8	25.0	33.3	58.3	
11	The information (such as online help, on-screen messages, etc. provided with this system is clear	8.3	25.0	27.8	38.9	66.7	
12	It is easy to find the information I needed	8.3	19.4	36.1	36.1	72.2	3
13	*The information provided for the system is easy to understand*	8.3	13.9	27.8	50.0	77.8	2
14	The information is effective in helping me complete the tasks and scenarios	5.6	25.0	19.4	50.0	69.4	4
15	The organization of information on the system screens is clear	5.6	27.8	13.9	50.0	63.9	
16	The interface of this system is pleasant	5.6	25.0	25.0	44.4	69.4	4
17	I like using the interface of this system	11.1	19.4	30.6	38.9	69.5	4

(*continued*)

Table 13. (*continued*)

No	Questionnaire's evaluation criteria	Likert scale Rank					
		4	5	6	7	6 + 7	
18	This system has all the functions and capabilities I expect it to have	11.1	19.4	25.0	44.4	69.4	4
19	Overall, I am satisfied with this system	5.6	13.9	33.3	47.2	80.5	1

These findings are almost identical to that of Groups 1 and 2, indicating that the respondents' demographics are rather homogeneous. Differences are minimal. Hence, Figs. 2a and b apply to all three groups, with slightly different weightage based on centrality in design, adapted to the respective demographics' capability maturity, risk acceptance and expectations.

6 Contributions

Contributions are:

1) the scaffolds for enhancing computational thinking skills, adding on to [36], the meta-analysis, which leads to the derived hierarchy of pragmatic and hedonistic factors based on CSUQ and CSUQ-HE-UEQ and that the chain of effects' descending order, reflected in the underlying mind maps and cultural adaptations are the intertwining DNA;
2) identification of approximate percentage that (non)ease-of-use factors account for via CSUQ;
3) ontological awareness and its possible potential have increased, along the SQL-noSQL and SQL vs. noSQL lines of thought. Hence, the SQL-vs. noSQL and SQL-noSQL analogy, which requires dynamic semi-structured evaluation, and loosely-coupled (dis)assembly.

7 Conclusion

This study has investigated three groups of students' perceptions towards what's important in design, via information systems analysis, design and development of prototypes, and via HE, CSUQ, UEQ evaluations. Student-designers have managed to identify key criteria in alpha testing, and refined their design correspondingly, in beta. Though rankings differ slightly, students are able to identify factors contributing to sustainability for the specific demographic. Findings reflect shifts in centralities of design and models at different points over time. These two groups' designs also reflect continuums and spectrums in notions of what sustainable interconnected systems in the metaverse may be like. Their artefacts and reports also indicate increased interest, and self-efficacy/confidence in designing and developing for interconnecting (non) metaverse (eco)systems.

There are however, limitations to the findings, as the sample size is small. Nevertheless, these findings point to problem-solving subspaces in atomistic contexts as viable, only when and media-rich and ontologically and loosely interconnected, to enable diverse

refactoring; similar to Lazada and Shoppee's success with e-commerce. Future work will include diverging frameworks, technologies and assessments.

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