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Abstract

There are known issues in authentic assessment design practices in digital education, which include the lack of freedom-of-choice, lack of focus on the multimodal nature of the digital process, and shortage of effective feedbacks. This study looks to identify an assessment design construct that overcomes these issues. Specifically, this study introduces an authentic assessment that combines gamification (G) with heutagogy (H) and multimodality (M) of assessments, building upon rich pool of multimodal data and learning analytics (A), known as GHMA. This is a skills-oriented assessment approach, where learners determine their own goals and create individualized multimodal artefacts, receive cognitive challenge through cognitively complex tasks structured in gamified non-linear learning paths, while reflecting on personal growth through personalized feedback derived from learning analytics. This pilot research looks to: (i) establish validity of all elements within the assessment design, and (ii) identify if application of assessment design leads to improved learner satisfaction. Results showed positive validations of all key elements of the GHMA assessment model, as beneficial factors tied to positive learner satisfaction on assessment delivery. There existed statistically significant post- and pre-treatment differences between experimental and control group satisfaction levels, indicating positive receptivity of GHMA authentic assessment design in digital education.

Keywords Authentic assessment design · Digital education · Pilot study · Gamified heutagogical multi-modal AI-driven (“GHMA”) approach · Learner experience and satisfaction

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1 Introduction

The need for digital literacy has pushed education to evolve its core digital curricular offerings to promote "*digital fluency*" in learners (Bryan et al., 2019), and strengthen them with digital competence supporting high-tech workplace success (Ulf-Daniel & Kellermann, 2019; Spante et al., 2018).

There are known issues surfaced in authentic assessment design practices in digital education, which include (i) the lack of "*freedom-of-choice*" " to address differing learning styles, extrinsic or intrinsic motivations, and talents (Blanschke & Marin, 2020; Nasab, 2015; Autio et al., 2011), (ii) the lack of focus on the multi-faceted and multimodal nature of the digital process (Niiranen, 2021; Jones & Buntting, 2013), and (iii) the shortage of effective feedback to reflect and transform learners' performances, leading to lower learning engagement and satisfaction (Vattøy et al., 2021; McCarthy, 2014).

To promote digital literacy and competence, a re-evaluation of authentic assessment design practices in digital education can be useful (Bryan et al., 2019).

To add to the present literature in this domain, this paper proposes a novel authentic assessment design approach known as GHMA (pronounced '*ga·muh*'), which combines gamification (G) with heutagogical (H) design elements applied on multimodal (M) assessments methods, informed by rich multimodal data and adaptive learning technologies (A).

This paper looks to achieve two objectives, namely to: (i) describe the novel GHMA authentic assessment design approach, and (ii) perform a pilot study, with the aims of establishing validity of the assessment design framework, and identifying if the application of the assessment design leads to improved learner satisfaction in digital education.

In the conduct of the pilot study, to (i) establish validity of all key elements within the assessment design, and (ii) identify if the application of the assessment design leads to improved learner satisfaction in digital education, we explore the following research questions (RQ):

RQ1. Are the key elements of the GHMA assessment design, namely (i) gamification, (ii) heutagogy, (iii) multimodality and (iv) learning analytics associated with receptive authentic assessment experience?
RQ2. Does the implementation of GHMA assessment design improve learning experience?

Results validated all key elements of GHMA assessment model, as beneficial factors tied to positive learner satisfaction on assessment delivery. There also existed statistically significant positive post- and pre- treatment differences between the experimental and control group satisfaction survey scores, which indicated positive receptivity of proposed assessment design.

By introducing and evaluating the usefulness of the formulation of the novel GHMA authentic assessment design, educators and researchers can understand how GHMA can be an utile and purposive tool in educators' assessment design toolkit.

2 Background

In a concept paper Curriculum for Digital Education Leadership by the Commonwealth of Learning, a cross-governmental organization representing 54 Commonwealth nations to promote education-related technologies, resources and knowledge, digital education is defined broadly as the "*process of teaching and learning involved in fostering capabilities that are needed for an individual to live, learn and work in a digital society"* (Brown et al., 2016). In particular, the key tenets of digital education include:

- Empowering learners with the ability to learn, live and work in a digitally-mediated society.
- Imbuing learners with the technical means to utilize and reproduce digital resources, and the capacity and agency as change agents to critique and develop innovative digital resources and practices in the existing or future social and market structures.
- Imbuing learners with the critical cognizance of digital culture and practices, and how these can impact and modify relationships, and social and market practices.

The U.S. Office of Educational Technology (2022) defines assessment as a purposeful measurement of learning to gather "*evidence of students' thinking during the learning process*". This study adopts the definition of authentic assessments by National Research Council (1996), as "*assessment exercises [that] require students to apply knowledge and reasoning to situations similar to those they will encounter in the world outside the classroom, as well as to situations that approximate how [professionals] do their work*".

Owing to the applied nature of digital education, there is a predilection towards connecting assessment activities to authentic and meaningful digital technology and innovation practices similar to the many manifestations of practicing technologists and innovators with diverse tools and processes. Educators incorporate workplace core-competencies of digital technology and innovation into assessment practices so that graduates reflect industry competencies (Fox-Turnbull, 2015; Williams, 2015).

In Assessment Design Toolkit endorsed by the U.S. Department of Education (2015), it highlights that "*assessment design… [to measure] what students know and can do is an essential part of teaching*". Villarroel et al. (2018), Ashford-Rowe, Herrington and Brown (2014), and Rennert-Ariev (2005) studied critical indicators that can help support authentic assessment design practices. Four common narratives include:

(1) *Contextualized realism*: Provide realistic tasks that contextualize to the workplace, including the perception of roles, experiences and practices.
(2) *Emancipatory control and decision making*: Give learners significant control over assessment context and conditions, so that there exist "empowerment to engage in autonomous actions arising out of authentic insights" for reflective evaluation.

(3) *Cognitive challenge*: Provide realistic and cognitively complex tasks that demonstrate the multi-faceted competence of the workplace.
(4) *Metacognitive evaluation and personalized feedback*: Provide deliberate personalized feedback, so that learners can reflect on personal growth and professional context of their work.

To address aforementioned issues and satisfy critical indicators that can help support authentic assessment practices in digital education, the study explores an authentic assessment design approach, incorporating the four elements:

(1) *Gamification*: Explore introduction of gamification to incorporate self-determination of assessment choices (Khaleel et al., 2020; Smiderle et al., 2020; Pardos et al., 2017).
(2) *Heutagogy*: Allow pre-assessment type-activity where student have greater "freedom-of-choice" to make heutagogical choices within assessment to ascertain relevance to self (Byker, 2016; Blaschke, 2012).
(3) *Multimodality*: Explore increasing modality of assessment to improve multi-faceted nature of digital competence (Smith et al., 2018; Crosslin & Wakefield, 2016).
(4) *Adaptive learning technologies*: Application of learning analytics to provide timely and extensive feedback and actionable learning intervention and inform assessment redesign (Jovanovic et al., 2018; Frederickson et al., 2005; Kennedy et al., 2014).

The four elements map to all four indicators of authentic assessment practice in the following way: (i) The ability to make heutagogical assessment choices and exercise control over assessment modalities help satisfy emancipatory control and decision making in the midst of cognitive development; (ii) Assessment gamification provides cognitive complexity that mirrors workplace choices and promotes active participation, while providing immediate feedback to learning challenges; (iii) Learning analytics promotes personalized feedback that can encourage metacognitive evaluation in learners; (iv) Workplace authenticity involves non-linear and multifaceted decision making – a sense of realism captured by a combination of the application of gamification, heutagogy and multimodality in assessments.

In this paper, to establish the validity of the assessment design framework, we study how GHMA assessment design brings about learner benefits of (i) control, (ii) cognitive challenge and (iii) feedback in assessments.

3 Assessment design framework

As shown in Fig. 1, the proposed GHMA assessment design is a skills-oriented game-based assessment approach, where learners can determine their own goals and create individualized multimodal artefacts (control), receive cognitive challenge through cognitively complex tasks structured in gamified non-linear

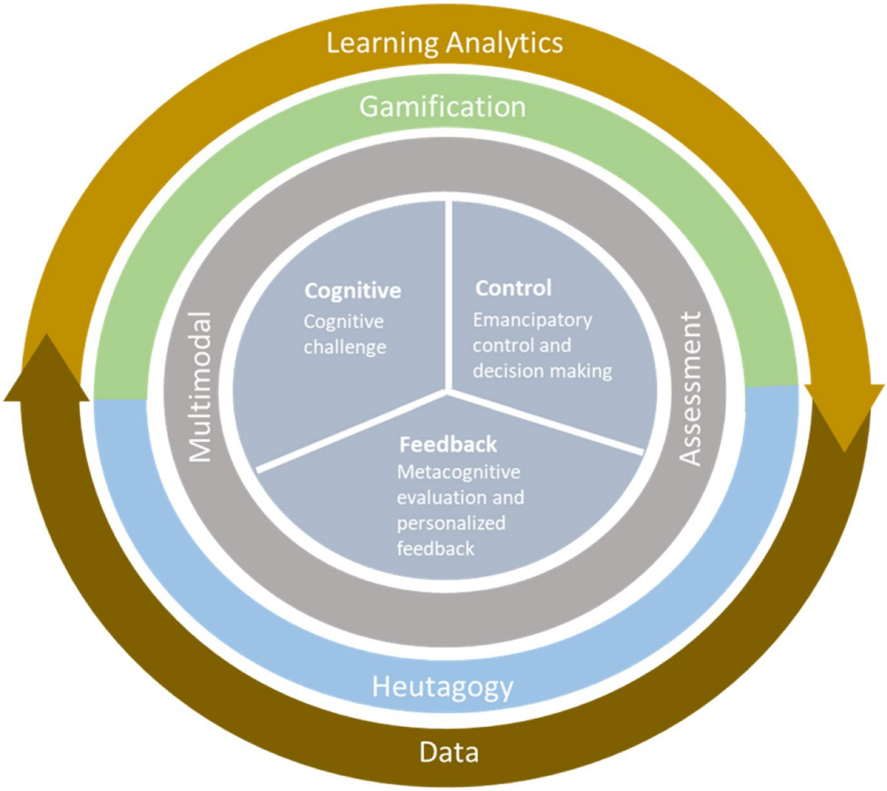


Fig. 1 GHMA assessment design built upon learning analytics and data extracted from the learning process

learning paths (cognitive), while reflecting on personal growth through personalized feedback derived from learning analytics (feedback). Assessment is to cater for careful selection and relevant digital tasks and activities, so that digital literacies and competencies are developed and nurtured. There is to be clearly defined goals, explicit rules, and a feedback system, such that assessment is aligned with the five elements of assessment design by U.S. Department of Education (2015).

In line with Crossline and Wakefield (2016), the proposed assessment design may be integrated in a course design utilizing a dual-layer course design methodology (Fig. 2). The underlying design strategy involves the creation of a set of course objectives and competencies, and learning outcomes, followed by the designing of a dual-layer approach to satisfy the learning outcomes.

The first layer involves instructor-centred instruction. The structured objectives and pre-determined instructional contents are useful to satisfy course competencies and learning outcomes, while forming the 'base knowledge' required for the course. Students build upon the base knowledge, in addition to

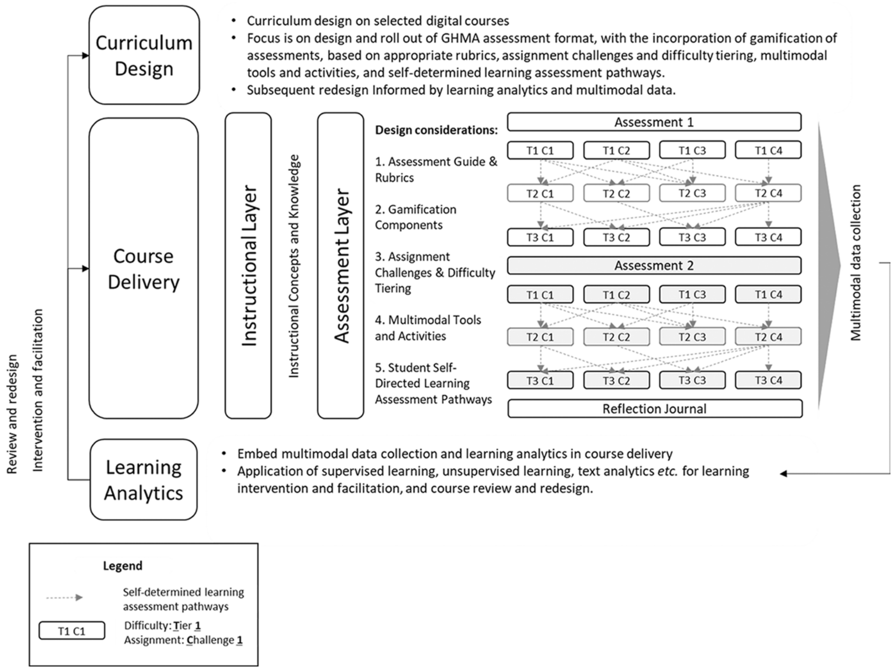


Fig. 2 Course design

instructor-recommended resources, student-researched resources and instructor-student consultations, to complete the course assessments.

The second layer is a student-centred assessment, build upon GHMA assessment design. This layer is central to the study. In this approach, each assessment comprises of multiple challenges (Gari et al., 2018). All challenges comprise of appropriate individual and group scoring rubrics. A challenge may lead to content unlocking, badges, and points, which will be reflected in a leaderboard. There may be a pre-specified number of challenges with different points assigned. Students will have to self-select and complete challenges of all levels of difficulty to clear the assessment, and each challenge may unlock other challenges within the assessment. Each student determines their individualized assessment pathway. Feedback for each challenge will be provided post-submission. Each student is to undertake a reflection journal at the end of the assessment to provide intentional and reflective consolidation of learning (Thurner et al., 2020).

An illustrative example of an assessment is shown in Fig. 3. We illustrate a Financial Technology (FinTech) course. In this illustration, challenges of lower levels of difficulty comprise of a written report on a FinTech application of financial inclusion, drawing up a comprehensive mapping of the FinTech landscape in a particular city, region or country, and the creation of a webpage to inform about selected FinTech technology application (e.g. robo-advisory) in FinTech etc. Challenges with higher levels of difficulty may comprise of the creation of a FinTech chatbot using online resources, recording video interviews of FinTech

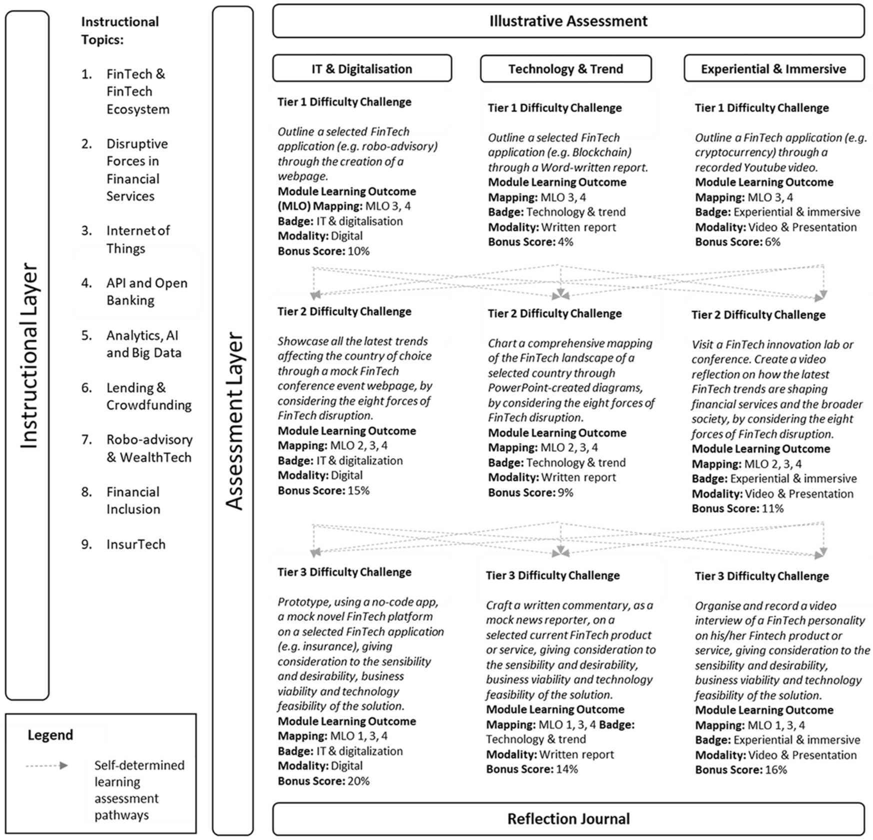


Fig. 3 Illustrative GHMA course design on a FinTech course

personalities on their learning and experiences of working in a FinTech startup, and the prototyping of a FinTech insurance platform etc.

The GHMA elements in the assessment design are as follows:

(1) *Gamification*: The gamification aspect of the assessment design is tied to the design integration of game components, including points, badges, leaderboard, levels, time constraint, feedback, clue, in non-linear learning paths.
(2) *Heutagogy*: The heutagogical aspect of assessment design is linked to students' customisation of assessment pathways to create individualised assessment experience (Crosslin & Wakefield, 2016).
(3) *Multimodality*: The multimodality aspect of assessment design is tied to the need for students to apply different media (or combinations of media) to create challenge or task artefacts. This may include media, such as report, podcast, video, role-play, digital or physical prototype etc. in assessment deliverables (Curwood, 2012; O'Halloran & Lim, 2011).

(4) *Adaptive Learning Technologies*: Underlying the GHMA assessment model is the embedding of multimodal data collection and application of learning analytics, for learning intervention and facilitation, and course review and redesign. Learning analytics, such as supervised and unsupervised learning, is implemented to augment and automate learning progress and gamified assessment outcomes tracking.

In the design of each challenge that are stackable for the completion of an assessment, cognitive load has to be taken into consideration, as managing cognitive load can help lower stress, errors and low performance, while enhancing learning (Prabhakharan et al., 2012). Further, assessment criteria and rubrics in GHMA are also important points of consideration. For this research, standardization of rubrics for equitable performance measurement will be the key departure from informal heutagogy (where learners may determine how they are assessed) to formal heutagogy (where standardized rubrics are provided as part of the explicit assessment rules). Effective assessment rubrics will be an important aspect of GHMA design.

4 Related works and learning theories underpinning proposed assessment design elements

4.1 Heutagogy

Heutagogy, or self-determined learning (SDL) principles (Hase & Kenyon, 2000) have a direct impact on fostering creativity and innovativeness in digital education. Heutagogy's core principles such as learner negotiation can enable greater learning ownership and learner agency, improving learners' learning capacities that can help them navigate complexity and uncertainty in the future workplace, encouraging lifelong learning in digital education (Halupa, 2021).

The heutagogic approach to learning is predominantly underpinned by the following learning theories (Blaschke & Hase, 2019), including (i) humanism, in terms of individual growth and learner choices (Hase & Kenyon, 2013); (ii) constructivism, in terms individual contextual connection to pre-existing learner knowledge and active learning process (Hase & Kenyon, 2013); (iii) connectivism, in terms of autonomy and learning choices via connectedness (Dron & Anderson, 2014; Blaschke, 2012); and (vi) self-regulated learning theory, in terms of learner responsibility and ownership in the learning process (Zimmerman, 2000).

According to Hase (2016), to incorporate heutagogy in assessment design, the following principles among others, should be considered: (i) promote flexibility to involve learner in designing individualized learning process; (ii) establish non-linear learning pathways; (iii) enable learners to contextualize concepts and knowledge; (iv) focus on experiential learning; (v) facilitate reflection; and (vi) provide a multitude of resources to let the learner explore.

In terms of authentic assessments in relation to digital education, among others, Lynch et al. (2021) proposed useful guidelines on how assessments in the domain of Internet Communication Technology (ICT) in higher education can be created via the heutagogical approach, including the practicality of rubrics and the value of authentic audiences.

4.2 Multimodality

In digital education, learners engage with digital language, semiotics and concepts in multimodal texts, objects and processes. Multimodal assessments enhance students' understanding of subject matters in digital education, through the interweaving of technical skills, composition elements, media and meaning to determine what ends up in such assignments as students' representations of their understanding of the subject matter (Curwood, 2012, p. 242). Multimodal assessments may utilize multiple media, such as digital publishing, podcast, digital storytelling, role-play, digital or physical prototype etc. in assessment deliverables to expand the dimensionality of the artefact, either through the use of different media in separate standalone submissions, or as a combination of media in a single submission.

The multimodality approach to learning is predominantly underpinned by the following learning theories, including (i) multiliteracies, in terms of understanding literacies as perspectival, context-dependent, multimodal, fluid (New London Group, 1996); and (ii) social semiotic theory of multimodality, in terms of how multimodal signs can be presented as assessment artefacts (Kress, 2009).

Öman and Sofkova Hashemi (2015) discusses about technology-mediated multimodal literacy and assessment activities, including multimodal composition and communication of different modes of expression in the form of linguistic, visual, auditory, gestural, and spatial. Jones, Buntting and de Vries (2013) discusses how such assessments can be in the form of e-portfolios which combines a multi-levelled and distributed nature of assessment activities, to form multi-perspective composition of learning evidence over time with opportunities for guidance and rich feedback.

4.3 Gamification

In educational settings, gamification is the leveraging of game dynamics, mechanics and components to solve a problem, promote learning effectiveness and cultivate desired learning behaviours (Klemke et al., 2018; Kapp, 2012). Gamification can improve student engagement and performance, while enhancing flow and enjoyment (Bitonto et al., 2014; De-Marcos et al., 2014; Sillaots, 2014). Gamification of assessment is "*a serious approach to accelerate the curve of the learning experience, teach complex subjects, and systems of thought*" (Kapp, 2012).

The gamification approach to learning is predominantly underpinned by the following learning theories (Krath et al., 2021), including (i) self-determination theory, in terms of the ability to initiate and regulate one's own actions, psychological need for competence and connectedness to others (Seaborn and Fels, 2015); (ii) flow theory, in terms of immersive deep learning and concentration (Perttula et al., 2017); (iii) experiential learning theory, in terms of personalized learning experience rather than instructivism (Wu et al., 2012); (iv) constructivism, in terms of active participation and self-reflection (Kordaki & Gousiou, 2017); and (v) situated learning theory, in terms of authentic learning to link to 'real world' scenarios, multimodal representation and ownership of learning (Dabbagh & Dass, 2013).

In terms of authentic assessments in relation to digital education, among others, Burd et al. (2018) shared a gamified project-based assessment approach using the 'Internet-of-Things (IoT) Service Kit', where learners may be assessed by constructing a physical IoT model based on authentic user stories for IoT systems derived from a board game. Kocadere and Caglar (2015) explores the implementation of a gamified assessment in an Educational Game Design course through the use of gamification components proposed by Werbach and Hunter (2012): avatars, levels, content unlocking, the leader board, achievements, virtual goods, points, teams and badges. The authors' findings demonstrate that this assessment process was an enjoyable one for all the students. Further, students reported that they were motivated, engaged well in learning and had lower exam anxiety during the assessments.

4.4 Learning analytics

Learning analytics is the "*measurement, collection, analysis, and reporting of data about the learners and their contexts for the purposes of understanding and optimizing learning and the environment in which it occurs*" (Siemens & Long, 2011). Application of learning analytics on assessments is useful to improve learner engagement, motivation and performance. It can also help to inform curricula design, provide feedback and support collaborative work of students (Ferguson, 2012).

Depending on how the system is constructed, learning theories such as constructivism or connectivism can apply (Banihashem & Macfadyen, 2021). However, there also exist a common denominator of learning theories that relates more to 'actionable intelligence', including (i) experiential learning, in terms of how data (observations) are collected from learner behavior (concrete experience), upon which metrics are derived (abstract conceptualization), for learning intervention to occur (active experimentation); and (ii) conversational framework, in terms of adaptations and feedback (Clow, 2012).

Adaptive learning technologies can be applied across a wide range of digital authentic assessments. In an undergraduate sports technology-related course, Liu and Zhu (2020) utilized an online authentic analytics-based personalised adaptive learning evaluation tool, integrated with an intelligent teaching assistant. Cognii, an AI-based Educational Technologies company, and Florida International University, partnered for the roll out of Cognii VLA to Information Systems Management students (King, 2019). Cognii VLA is an intelligent AI tutoring system that provides authentic subject matter-based assessments and instantaneous chatbot-style feedback using natural language conversations to learners, while providing pedagogical insights and analytics to faculty members.

5 Conceptual framework and research methodology

5.1 Research design and variables

To (i) establish validity of all key elements within the assessment design, and (ii) identify if the application of the assessment design leads to improved learner satisfaction in digital education, we explore the following research questions (RQ) and their respective hypothesis (H):

(1) RQ1: Are the key elements of the GHMA assessment design, namely (i) gamification, (ii) heutagogy, (iii) multimodality and (iv) learning analytics associated with receptive authentic assessment experience?
H1: Learner satisfaction is associated with receptivity to (i) gamification, (ii) heutagogy, (iii) multimodality and (iv) learning analytics elements in the GHMA assessment design.
(2) RQ2: Does the implementation of GHMA assessment design improve learning experience?
H2: Learner satisfaction is different between experimental group exposed to GHMA format of assessment and control group exposed to traditional assessment design.

To test H2, we compare learner satisfaction of student exposed to GHMA assessment (experimental group), with traditional assessment (control group). The latter refers to the 'conventional' methods of evaluation, such as written quizzes with multiple-choice, true-false statements, fill-in-the-blanks, and open-ended structured questions, and essay examinations (Nasab, 2015; Struyven et al., 2005).

Research methodology applied under this study is a blend of methodologies applied in Lizzio and Wilson (2013), Breu and Yasseri (2022) and Preston et al. (2020). A pilot study is undertaken to provide validation on the effectiveness of GHMA assessment design on a selected digital course for learner satisfaction.

Conceptual framework developed in Fig. 4 helps in the understanding of the research design.

To determine H1, research conducted structural equation modelling to examine the direct and indirect relationships between the exogenous GHMA variables, latent constructs representing authentic assessment indicators and endogenous variable representing learning satisfaction, and the extent to which the conceptual model fitted the empirical data (Lizzio & Wilson, 2013).

To determine H2 and to model changes in satisfaction levels pre- and post-assessment between the experimental and control groups, research performed differences-in-differences (DID) estimation using hierarchical linear regression on time and treatment variables, with reference to the satisfaction score. In particular, the first-level difference was the within-group changes in satisfaction levels pre- and post-assessment, and the second-level difference was the discrepancy across groups pre- and post-assessment. To minimize multicollinearity, research standardized the variables using z-transformation (Breu & Yasseri, 2022; Aiken et al., 1991).

We model the level of learner satisfaction sat_{it} for experimental groups i at time t as follows (1):

$$at_{it} = \beta_0 + \beta_1 treat_i + \beta_2 time_t + \beta_3 treat_i * time_t + \beta_n C_n + \varepsilon_{it} \tag{1}$$

where $treat_i$ represent the experimental group $(i=1)$ against the control group $(i=0)$. $time_t$ represents the time indicator of post- $(t=1)$ or pre- $(t=0)$ assessment

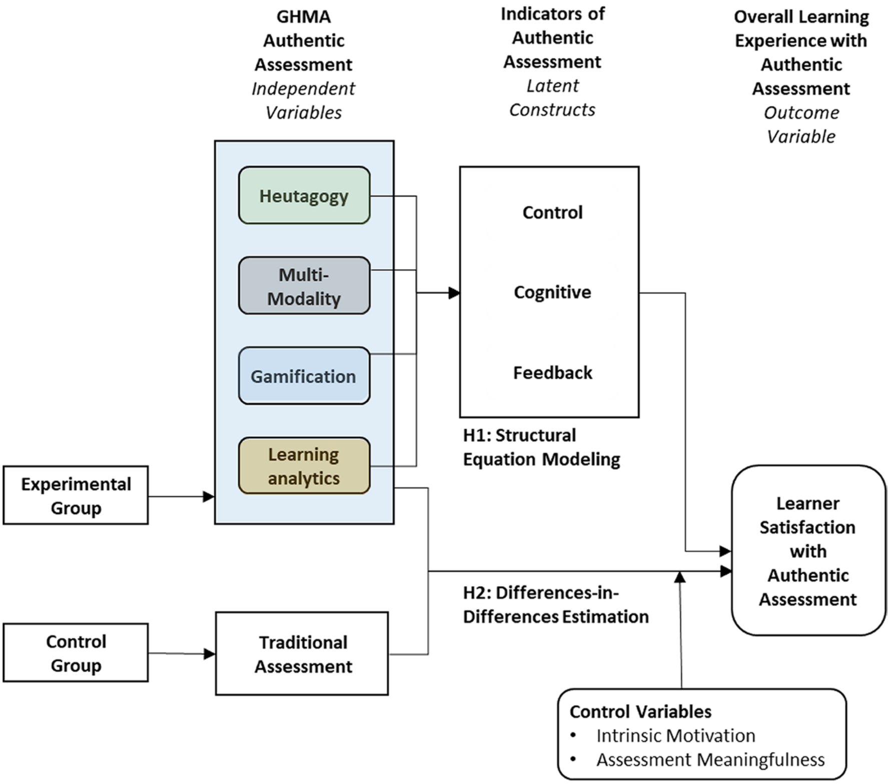


Fig. 4 Conceptual framework and research design mapping

exposure. An interaction term computed from $treat_i$*$time_t$ represents the DID estimation. Vector of control variables C_n represents control variables that influences learning including intrinsic motivation and assessment meaningfulness.

5.2 Survey instrument

Quantitative data comprised of learners' self-reported assessment perceptions were collected through anonymized online questionnaires. In a small-scale pilot, a 30-question pre-and post-assessment survey was designed to capture responses relating to hypotheses H1 and H2, as shown in Table 1. This is a likert-scale type survey with 1 representing responses tied to '*strongly disagree*' and 10 representing '*strongly agree*'. Questions mapped to the following variables: (i) dependent variable: *Learner Satisfaction*, as measured by learner's self-perception of learning experience (*sat*); and independent variables: *Heutagogy (heu), Multimodal (mul), Gamification (gam), Learning Analytics (la), Intrinsic Motivation (ctl_im)* (control

Table 1 Pilot survey questions

Variable	Survey Question
Learner Satisfaction (sat)	*sat*: Overall learning experience.
Heutagogy (heu)	*heu1*: I set assessment goals. *heu2*: I was proactive in discussing assessment activities. *heu3*: I was able to complete the assessment activities on my own. *heu4*: I was focused on finishing the assessment without supervision. *heu5*: I felt in control of my own learning. *heu6*: I was able to determine how I was assessed. *heu7*: I discussed with my lecturer to decide how I preferred to be assessed. *heu8*: The assessments are flexible.
Multimodal (mul)	*mul1*: I prefer choosing the assessment type e.g. videos, reports, presentations for submission. *mul2*: Choosing the assessment type help me feel more engaged in this module. *mul3*: Being able to choose the assessment type motivates me in this module. *mul4*: I was able to choose an assessment type that plays to my strengths. *mul5*: Completing different assessment types made learning fun.
Gamification (gam)	*gam1*: The challenging elements e.g. levels, badges, time constraint, made assessment engaging. *gam2*: Achieving goals while playing games give me a sense of accomplishment in this module. *gam3*: I found the assessment engaging because it challenges me. *gam4*: The different levels of assessment tasks provide a sense of challenge.
Learning Analytics (LA)	*la1*: Analytics-derived timely feedback to improve performance. *la2*: Analytics-derived timely feedback to improve understanding. *la3*: Analytics-derived effective and well-designed learning intervention.
Control Variable: Intrinsic Motivation (IM)	*ctl_im1*: I am motivated to learn, regardless of the module. *ctl_im2*: I often complete assessment activities, regardless of the module. *ctl_im3*: I am motivated to attempt harder assessment activities, regardless of the module. *ctl_im4*: I am seldom distracted when completing assessments, regardless of the module.
Control Variable: Assessment Meaningfulness (AM)	*ctl_am1*: What I learnt in this module is necessary for success in the future. *ctl_am2*: I am able to apply what I learnt from other modules for the assessment. *ctl_am3*: In this module, new topics are connected to what I learnt previously. *ctl_am4*: In this module, the skills I learnt are important. *ctl_am5*: In this module, the assessment activities allow me to explore new things.

variable) and *Assessment Meaningfulness (ctl_am)* (control variable), as measured by their respective survey items.

Reliability of the questionnaire was tested by computing Cronbach's Alpha coefficient. Descriptive statistics of learners' satisfaction, namely frequencies, minimums, maximums, means and standard deviations were computed for the pre-post experimental and control groups. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was investigated to determine if factor analyses were appropriate.

6 Pilot study

A pilot assessment was conducted upon a sports technology-related course, known as Fitness Club Management (FCM) which comprises both digital and physical elements. The pilot study was conducted on four runs of this module in 2021, forming a pilot sample size of 96 anonymized and voluntary participants. The students were a homogenous profile of students from the Diploma in Sports and Wellness, with ages ranging from 18 to 22.

To ensure minimal confounding factors, this pilot experiment was a controlled experimental A/B testing applied on back-to-back cohorts of the same course of homogeneous student profile, using GHMA assessment (experimental group) for one course and traditional assessment (control group) for the other (Smiderle et al., 2020). Pilot study was conducted on FCM students across four module runs, consisting of two module runs of control group and two module runs of experimental group. In summary:

- *Control group*: This group consisted of voluntary and anonymized participants from two runs of FCM course exposed to non-GHMA traditional assessment. Here, we apply 'conventional' written quizzes with a combination of multiple-choice questions and open-ended essay questions Survey results from this group acted as the baseline.
- *Experimental group*: Voluntary and anonymized participants from two runs of FCM course exposed to GHMA assessment.

From the module learning objectives (MLO), there were three domains of competency that students would need to accomplish, namely attaining (i) knowledge and conceptual competency on fitness training, (ii) fitness and exercise performance competency, and (iii) relationship management competency relating to FCM. These three domains would represent three badges of accomplishment. There were also three assessment submission formats or modalities, namely (i) live presentation via social media, (ii) digital recorded video, and (iii) digital web publication. The badge earned for domain knowledge and conceptual development will be assessed based on the live presentation via social media modality; the badge earned for client relationship management will be assessed based on the recorded Youtube video modality; the badge earned for domain fitness and exercise performance will be assessed based on digital web publications modality.

Learners kickstarted the assessment by self-selecting any one of the challenges across the three domains in level 1. Upon completion of the challenge assessment at level 1, students move up to the next level. They would have to select a challenge from another domain area. Upon completion of all three levels of the assessment, students would have to write and submit a written reflection journal to reflect upon their learning across the three levels of challenge assessment. Refer to Fig. 5 for an illustrative GHMA assessment design of the pilot study.

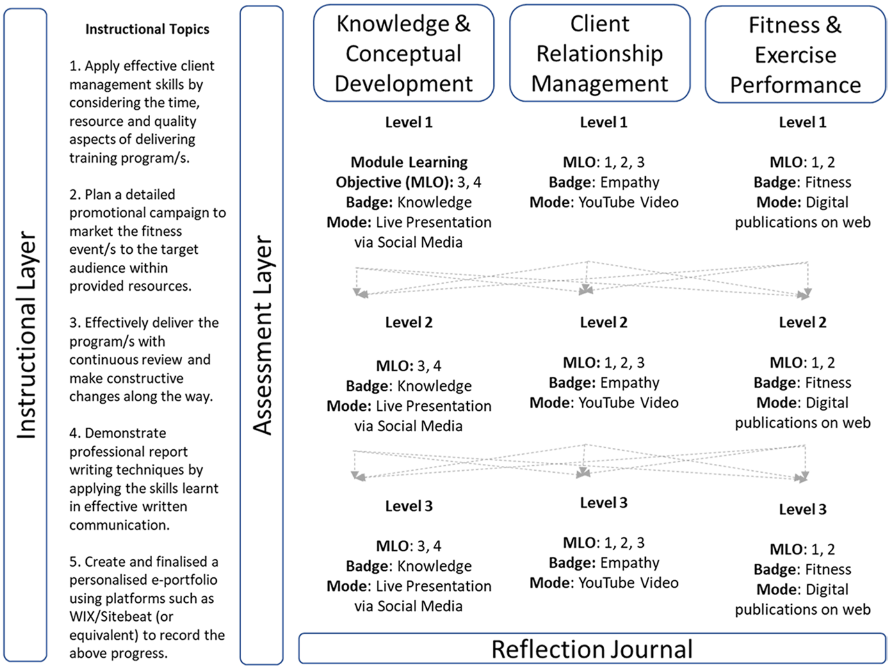


Fig. 5 Illustrative GHMA assessment design of pilot study

Learning analytics were performed on (i) pre-course behavioral profiling, (ii) pre-course expectation, (iii) assessment choices and non-linear learning pathways, (iv) grades for each assessment choice and overall grade, (v) problems logged, and (vi) interim and overall feedback.

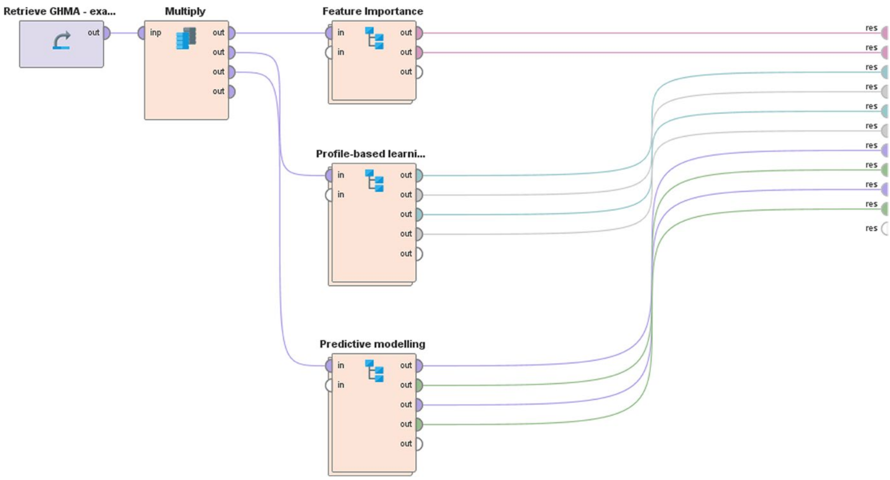


Fig. 6 Overall analytics architecture

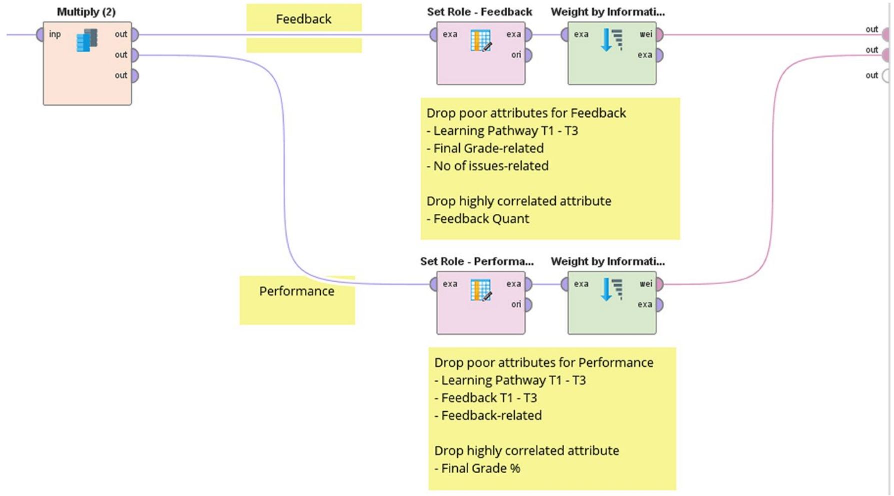


Fig. 7 Feature selection

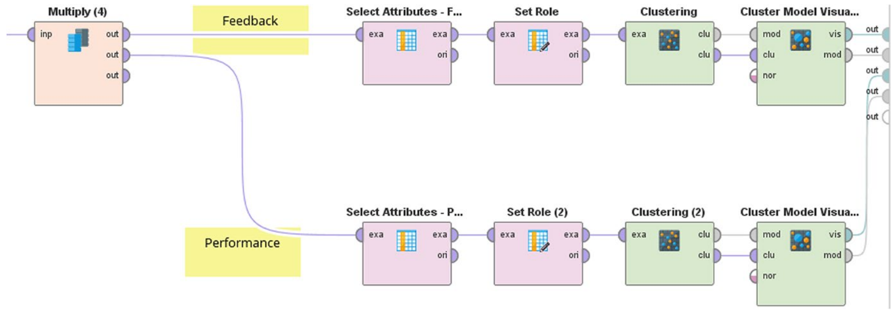


Fig. 8 Learner profile clustering

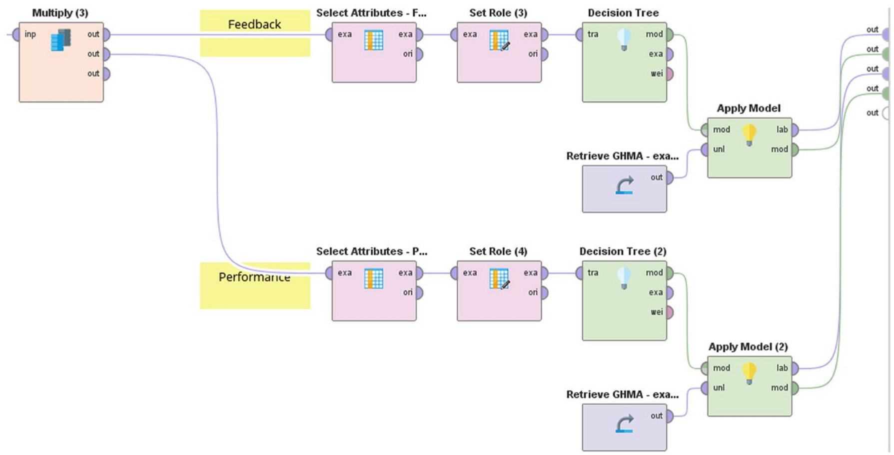


Fig. 9 Predictive modeling

Table 2 Descriptive summary of dependent variable *Learner Satisfaction*

		Likert survey response scores			
Treatment	Time	Min.	Max	Mean	Std Dev
Experimental	Post	6	10	8.05	1.28
Control	Post	4	10	7.36	1.40
Experimental	Pre	4	10	8.68	1.22
Control	Pre	4	10	7.52	1.89
Overall		**4**	**10**	**7.90**	**1.45**

Note: 1 represents 'strong disagree'; 10 represents 'strongly agree

Implementation of learning analytics was deployed using RapidMiner Studio. Figure 6 illustrates the overall analytics architecture. Figure 7 shows the feature selection process, where we retain only the key contributing attributes and drop attributes exhibiting multi-collinearity. Figures 8 and 9 show the learner profile clustering and predictive modeling processes, which help identify learner intervention areas.

7 Results

Mean, standard deviation and min-max range of the overall pre- and post-course survey satisfaction scores are shown in Table 2.

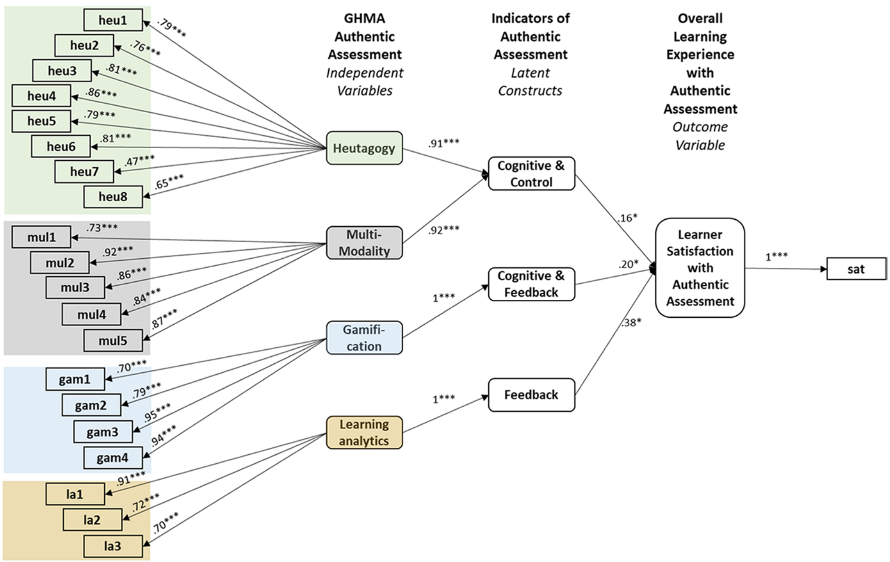


Fig. 10 Structural equation model. *Significance at the 0.05 level; **Significance at the 0.01 level; ***Significance at the 0.001 level

Survey instrument exhibited internal consistency and high reliability, indicated by Cronbach's Alpha of 0.96. KMO measure of 0.9 reflected a highly structured dataset appropriate for factor analyses.

7.1 Results for hypothesis H1

The study performed structural equation modeling using the R package lavaan. Analysis yielded a good level of fit of the model to data, with the following statistics: χ^2(182) = 20.325; Comparative Fit index (CFI) = 0.909; Tucker-Lewis Index (TLI) = 0.905; Standardized root means quare residual (SRMR) = 0.076; and Root mean square error of approximation (RMSEA) = 0.035. A good model fit is represented by high measures of incremental fit, generally above 0.9, with 1 being the best; and measures of residual variance, with RMSEA recommended to be lower than 0.08 (Hu & Bentler, 1999). Figure 10 provides a simplified presentation of the model.

Survey items mapped well to the latent variables representing the four GHMA model elements, at statistical significance of less than 0.001 level; in turn, the GHMA model elements mapped well to the latent constructs of authentic assessment indicators control, cognitive and feedback, at statistical significance of less than 0.001 level.

All authentic assessment indicators significantly positively predicted the overall level of learner satisfaction with the GHMA authentic assessment. The clear association is consistent with H1, proving that the four GHMA elements are beneficial factors tied to positive satisfaction on authentic assessment design.

7.2 Results for hypothesis H2

To test the study's research question if the implementation of GHMA assessment is effective at improving satisfaction scores, the study computed the DID estimator to compute the differences in average changes between the experimental and control group. Results of H2 are shown in Table 3.

The base specification, model (1) ($sat_{it} = \beta_0 + \beta_1 treat_i + \beta_2 time_t + \beta_3 treat_i * time_t + \varepsilon_{it}$), is statistically robust to be an acceptable model, demonstrating statistically significant differences between the experimental and control group pre- and post- treatment satisfaction levels. To account for potential confounding factors, the study performed regression analysis with the addition of two control variables – intrinsic motivation and assessment meaningfulness. Regression analysis found that Model (3) ($sat_{it} = \beta_0 + \beta_1 treat_i + \beta_2 time_t + \beta_3 treat_i * time_t + \beta_4 ctl\_am_4 + \varepsilon_{it}$) is the preferred model, with an adjusted r-squared of 0.609. The average difference between the experimental and control group pre- and post- treatment satisfaction levels (Fig. 11) is estimated at 1.134 at 0.001 level of significance. For a satisfaction level range between 0 and 10, a statistically significant difference of 1.134 represents a strong result. For this pilot study, these results indicate outperformance of GHMA against traditional authentic assessment format in digital education.

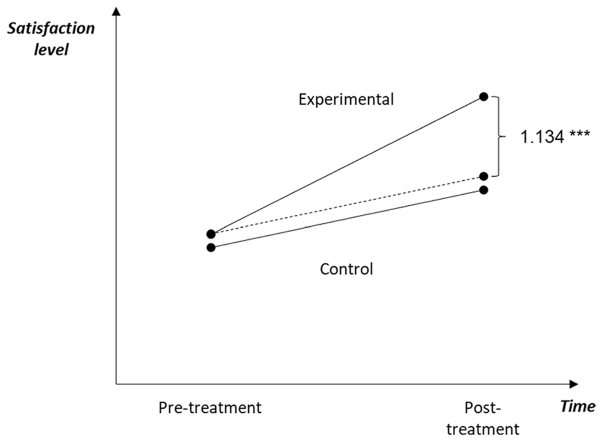
Table 3 Regression results

Regressor	(1)	(2)	(3)	(4)
Intercept	-0.033 (0.080)	-0.033 (0.080)	-0.033 (0.064)	-0.034 (0.064)
Time (*time*)	0.504*** (0.080)	0.502*** (0.081)	0.455*** (0.065)	0.452*** (0.065)
Treatment (*treat*)	0.278*** (0.080)	0.277*** (0.081)	0.194** (0.066)	0.192** (0.066)
DID (*treat*time*)	0.233 ** (0.081)	0.237 ** (0.081)	0.238 *** (0.065)	0.243 *** (0.065)
Control variables				
Intrinsic Motivation (*ctl_im*)		0.037 (0.080)		0.047 (0.050)
Assessment Meaningfulness (*ctl_am*)			0.474*** (0.065)	0.475*** (0.068)
Summary Statistics				
SER	0.779	0.783	0.625	0.627
Adjusted R^2	0.393	0.387	0.609	0.607
N	96	96	96	96

Column (1) represents the base specification and columns (2) to (4) represent alternative specifications with control variables

*Significance at the 0.05 level; **Significance at the 0.01 level; ***Significance at the 0.001 level

Fig. 11 DID estimator



8 Discussion and conclusion

There are known issues in authentic assessment design practices in digital education, which include the lack of "*freedom-of-choice*", the lack of focus on the multimodal nature of the digital process, and the shortage of effective feedback.

This study looks to identify an assessment design construct that overcomes these issues. Specifically, this study introduces an authentic assessment that combines gamification (G) with heutagogy (H) and multimodality (M) of assessments, building upon rich pool of multimodal data and learning analytics (A), known as GHMA. The proposed GHMA assessment design is a skills-oriented game-based assessment approach, where learners can determine their own goals and create individualized multimodal artefacts, receive cognitive challenge through cognitively complex tasks structured in gamified non-linear learning paths, while reflecting on personal growth through personalized feedback derived from learning analytics.

This pilot research looks to: (i) establish validity of all key elements within the assessment design, and (ii) identify if the application of the assessment design leads to improved learner satisfaction in digital education.

Results showed positive validations of all key attributes of the GHMA assessment model, as beneficial factors tied to positive learner satisfaction on authentic assessment delivery. This establishes the validity of all key elements within the assessment design. Further there existed statistically significant positive post- and pre- treatment differences between the experimental and control group satisfaction survey scores, indicating positive receptivity of GHMA authentic assessment design in digital education.

Learners' self-perceived benefits of heutagogy and multimodality in assessment design appear to be associated with their ability to make heutagogical assessment choices and exercise control over assessment modalities that help satisfy emancipatory control and decision making in the midst of cognitive development. Learners' self-perceived benefits of gamification appear to be associated with the cognitive complexity of the assessment that mirrors workplace choices and promotes active participation, while providing immediate feedback to learning challenges. In addition, learners' self-perceived benefits of learning analytics appear to be associated with the personalized feedback learners receive, that encourages metacognitive evaluation in them.

While the four key components above anchor the assessment design format, proposed solution also looks at integrating personal learning reflection as an assessment milestone to promote intentional and reflective learning in the creation process of task or project artefacts (Thurner et al., 2020). Interestingly, the use of reflective practice integrates well with heutagogical learning approach, as supported by Blaschke and Brindley (2011). Curriculum design may also emphasize on constructive and engaging teacher-student interactions to promote students' self-esteem, sense of efficacy and intrinsic learning motivation (Autio et al., 2011), especially through individualised feedback through learning analytics. Authenticity of assessments can further be enhanced through authentic audiences and collaborative learning.

Future studies can apply the proposed assessment design on multidisciplinary digital education to enhance learner emancipatory control and agency, metacognitive evaluation and personalized feedback, and cognitive skills, through attestation of research hypotheses in large scale research sample size. Future studies can also share findings of the development of large-scale transferable assessment designs and successful integration in digital courses benefiting greater number of learners.

Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval Ethics approval has been received for the conduct of this study.

Conflicts of interests/Competing interests The authors have no relevant financial or non-financial interests to disclose.

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