Education Tech Research Dev (2024) 72:947–972
https://doi.org/10.1007/s11423-023-10308-y

DEVELOPMENT ARTICLE

Design principles to develop digital innovation skills: a design-based research approach

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Accepted: 10 October 2023 / Published online: 10 November 2023

Abstract
The digitisation of the world has led to a multitude of far-reaching implications that require students to be prepared for the dynamic era of rapid change, complexity, fluidity, and ubiquity in which they will work at the forefront of technology. To succeed in this environment, students must be able to design and implement digital innovations within the broader spectrum of digital transformation. Despite the importance of this area, the literature shows a lack of research on how digital business innovation skills can be effectively taught to students. To address this gap, a design-based research (DBR) study was conducted using a mixed-methods design through three iterations at a South African university. The study aimed to answer the research question of how digital business innovation skills should be taught to South African Information Systems students. The study commenced with an analysis of practical problems experienced by practitioners, industry, students, and researchers and an initial review of pertinent literature. The literature review focused on the impact of digitisation on future skills requirements to inform the pedagogy, content, and technology applicable to the teaching and learning environment. The findings yielded design principles for the design of the learning environment that were tested and refined via three iterations, resulting in nine design principles. The aim was to ensure a future-oriented, industry-informed curriculum design that is relevant to the digital economy.

Keywords Design-based research · Digital innovation · Authentic learning · Future work · Design principles

Introduction

Advances in digital technologies are transforming society and the way we live and work, with digital innovation being a major driver of these changes (Bogers et al., 2022). Digital innovation refers to the creation of new market offerings, business processes, or models

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resulting from the use of digital technology (Nambisan et al., 2017). This shift towards a digital future requires a new type of citizen who can function in more unstructured and unpredictable circumstances. Higher education institutions (HEIs) must adapt by offering effective, innovative, and high-quality learning experiences that equip students with the necessary skills for a changing labour market (Alexander et al., 2019).

As we move towards a more digital world, the demand for higher-order general cognitive skills such as problem-solving, critical thinking, innovation, creativity, and collaboration is increasing (Djankov et al., 2019). Additionally, socio-emotional skills such as collaboration, teamwork, resilience, and adaptability are becoming increasingly important (ibid, 2019). In the field of Information Systems (IS), the general skills needed are moving beyond technical expertise to include higher-level integration and the role of cognitive skills (van den Berg, 2019; Goulart & Liboni, 2022).

This paper focuses on defining the skills requirements of IS students to become competent digital innovators and to develop design principles to teach digital innovation, ensuring industry-informed curriculum design that is future-proof within a digital economy. Validated design principles that can be adopted by future developers to design learning environments that enhance digital innovation capabilities are proposed. These design principles were developed and refined via a four-phased design-based research (DBR) approach as proposed by Reeves (2006). This paper contributes to DBR literature by providing insight into the process followed to articulate validated design principles while also sharing reflections. The paper commences with a review of the development of digital innovation skills. Subsequently, the application of DBR and the methodology applied are presented. The results of the three iterations are then discussed by focussing on a portion of the analysis applied in each iteration. The paper concludes with the recommended design principles that can be applied to teach digital innovation skills.

Developing digital innovation skills

The focus of the study was on digital innovation and not digital transformation due to the ability to implement digital innovations in individual areas of an organisation whereas digital transformation refers to systemwide, long-term change. Digital innovation foregrounds new digital products and services, whilst digital transformation is the application of digital technologies to transform an organisation's operations and culture.

A digital innovator can see new possibilities created by advances in technology that meet organisational or societal needs (Fichman et al., 2014). Digital innovation is the recombination of something that already exists with new technology and follows a nonlinear pattern of innovation diffusion to change the ways products and services are developed, produced and used (Bogers et al., 2022).

In the study, the first objective was to identify the skills required by IS students to develop the competence to be digital innovators. The umbrella term used to describe the type of skills that students will need in the digital economy is "21st-century skills" (21st CS). Many different frameworks identify 21st CS, but the one deemed to be the most comprehensive was a study by Kereluik et al. (2013). They compared more than 15 frameworks to identify the types of knowledge claimed to be integral to 21st CS. This framework was used to test different skill sets and to identify the most prominent skills required to develop digital innovation capability. Figure 1 illustrates this framework.

The development of certain 21st-century skills to teach digital business innovation can be enhanced by an authentic learning environment in which students must be "engaged in an

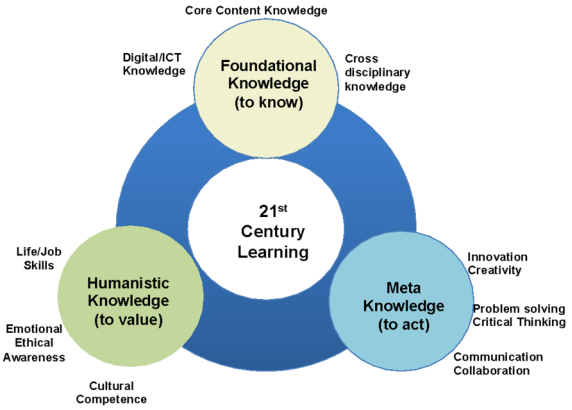

Fig. 1 Synthesis of 15 different 21st-century learning frameworks into one visual image (Kereluik et al., 2013)

inventive and realistic task that provides opportunities for complex collaborative activities" (Herrington et al., 2010, p. 1). The principles of authentic learning as outlined in Herrington et al. (2010) are described in Table 1 with a practical application attached to each principle as applicable to the cultivation of digital innovation skills.

Design-based research

The study is situated within the paradigm of design research. Design science research in the field of Information Systems (IS) is characterised by the use of human creativity to develop innovative artefacts that address problems in digital environments (Hevner & Chatterjee, 2010). This type of research employs design cycles to test and refine solutions, with an emphasis on the design and implementation of novel artefacts that contribute to the advancement of the field of digital innovation (Hevner et al., 2019).

Design research applied in an educational setting follows a similar process of iterative development of solutions to complex and practical educational issues (McKenney & Reeves, 2019). The fundamental premise of design research is to apply theory to ground the design process, with the ultimate goal of expanding scientific understanding. This approach is collaborative, with input from multiple stakeholders representing different disciplines within iterative cycles of design, development, testing, and revision (McKenney & Reeves, 2019).

Design-based research (DBR) is an iterative approach that involves continuous design cycles within authentic learning settings to test and refine theories and advance practice. DBR studies use a mixed-methods design and involve multiple parties such as designers, researchers, and practitioners with diverse expertise to guide the design, conduct, and reporting of the research (McKenney & Reeves, 2021). This approach allows for the development of practical and effective solutions to real-world problems within educational settings and is an effective methodology for advancing educational practice (McKenney & Reeves, 2019; Reeves, 2006).

The four phases applied to this study are illustrated in Fig. 2

Table 1 Implementation of an authentic learning environment in course design

Authentic learning elements	Implementation in course design
Provide authentic contexts that reflect the way knowledge will be used in real life	Form working partnerships with NGOs and community organisations to identify problems/solutions and implement a real, workable digital solution such as a website, mobile applications, databases, and data integration
Provide access to expert performances and the modelling of processes	Lecturer facilitation in class, peer reviews during class presentations and online peer review and feedback. Establish online communities of practice using, for example, Google Drive
Provide multiple roles and perspectives	Group work on projects that apply multiple models such as design thinking, business model canvas and scenario planning. Students ought to source their information, reflect on it and share their perspectives with their peers via blogs and discussions on Google Drive
Support collaborative learning	Working in teams and with clients, online collaboration, peer reviews and rubrics need to assess whole group collaboration
Promote reflection to enable abstractions to be formed	Personal blogs with weekly reflection on learning outcomes and experience, with added exercises for personal development. Peer reviews on blogs and online comments
Promote articulation to enable tacit knowledge to be made explicit	Weekly presentations during class time and individual check-ins to discuss the growing understanding of topics covered. Facilitation during face-to-face and online collaboration
Provide coaching and scaffolding by the teacher at critical times	Weekly analysis, feedback ability to improve, online guidance
Provide for authentic assessment of learning within the tasks	Students are required to implement a workable digital innovation (artefact) in organisations via a capstone project that lasts the entire semester and sometimes beyond. The project is formatively assessed during the roll-out

Method

Phase 1: stakeholder consultation and a review of the literature

In a DBR study, the design principles are collaboratively developed among various stakeholders and underpinned by a review of the literature. The problems are explored by parties who deal with them on a day-to-day basis via a consultative process such as participant observation and conversation, interviews, focus groups or reflective journals and blogs (Herrington & Reeves, 2011; Herrington et al., 2010). In this study, consultations with industry participants, students and higher education practitioners in IS were conducted via interviews and focus groups see Table 1, Phase 1.

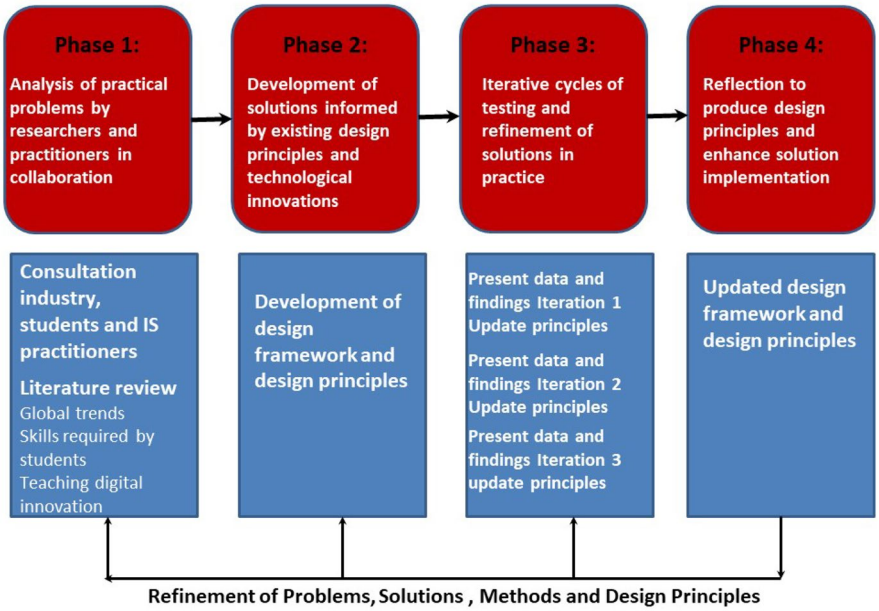

Fig. 2 Adapted from Design-based research approaches in educational technology research (Reeves, 2006)

Phase 2: development of solutions

During this phase, the literature review was extended to find additional theories and existing design principles that address similar problems. This was further expanded to create the draft design principles.

Phase 3: iterative cycles of testing and refinement

According to Herrington and Reeves (2011), a single implementation cannot gather enough evidence about the success of the intervention prompting which prompted three iterations over three consecutive years. After each iteration, changes were made to improve the design to better address the problem in the subsequent iteration. Phase 1 and 2 required empirical research to be conducted and the data collection and analysis are depicted in Tables 2, 3.

Phase 4: design principles

Once a learning design or intervention had been implemented, evaluated and refined in cycles, the last phase was to reflect on the entire process to produce design principles that could inform future development and implementation decisions. The aim is to provide at least three useful outcomes namely the design principles, a representation of the

Table 2 Methodology for data collection and analysis during the three iterations

Research Goal	Data Collection	Analysis
Phase 1 Perception of skills requirements and discrepancies in current IS curriculum to meet expectations	Sample: 200 s-year IS students and 30 third-year IS students Survey on Google Forms and Voice recordings providing group feedback	Mixed-Method Triangulation Design: Convergence Model (Creswell & Plano Clark, 2011)
	Sample: 20 students in the third year of is personal interviews	Qualitative
Expectations from is graduates in terms of skills requirements	Sample: 10 industry participants personal interviews	Qualitative
IS curriculum gaps to meet demands from industry and digital transformation	Sample: Seven lecturers in IS at a university in Cape Town Personal Interviews	Qualitative
Phase 3 test draft design principles in teaching and learning environments to determine perceived skills development Test student conduct during project implementation test the usefulness of digital innovation implementation	The sample for Iteration 1 was 40 post-graduate students in IS; Iteration 2 sampled 39 IS students in their final year and the sample for Iteration 3 consisted of 30 IS students in their final year Pre-test and post-test research survey on Google Forms: The survey questions were adapted from the Student Success Toolkit (George, 2015) using a five-point Likert scale. The knowledge tested in the survey stems from the framework by Kereluik, et al. (2013) as depicted in Fig. 1. Example of the survey	Quantitative: Multiple Regression and ANOVA Qualitative Analyse surveys and identity themes and subtheme codes from open-ended questions
	Student Blogs: Students were further required to subscribe to a blog and submit three blogs during the semester. The blog posts were used as a space where they could reflect on their progress during the semester, and they were also encouraged to share their experiences with other students, who could give feedback to them	Qualitative The steps prescribed by Miles and Huberman (1994) to systematically organise the data were applied in the analysis of blogs to identify codes and themes
	Students worked in groups of five to implement a practical project where they implemented a digital innovation e.g., (a mobile application or website). Students worked with industry partners to identify business model innovations and then through a process of design thinking, design and develop digital innovation artefacts. The teams could apply a selection of open-source software solutions to design and develop their artefacts (these were continuously tested and updated according to the project requirements)	Analysis of project documentation in Google Drive for an overview of progress. Record findings in facilitator reflection logs Digital innovation artefacts developed
	Reflections per week on student progress and constraints experienced during project implementations	Qualitative review to document changes to design principles

Table 2 (continued)

Research Goal	Data Collection	Analysis
Test student conduct during project implementation test the usefulness of digital innovation implementation	Post-test research survey to industry partners that participated in the student project implementations to measure the success of the digital innovation implementation. The questionnaire contained 30 questions regarding student conduct, understanding of business needs, ability to collaborate, the usefulness of the digital innovation implemented and the industry partner's overall digital savvy before and after the intervention in their business	Mixed-Method Quantitative applied a six-point Likert scale Qualitative analysis of open-ended questions

Table 3 Codes for testing skills sets and teaching and learning environment

Code	Description	Mapping of questionnaire questions
Skill sets		
S1	Cross-disciplinary	24, 31, 43
S2	ICT/digital knowledge	22, 23, 26, 27
S3	Communication/collaboration	8, 11, 12, 16, 17, 18, 19, 22
S4	Creativity/innovation	28, 29, 30, 32
S5	Critical thinking/problem solving	29, 44, 45, 46
S6	Life/job skills	10, 34, 35, 36, 37, 38, 40, 43
S7	EQ/ethics	15, 33, 39, 47, 48,
S8	Cultural competencies	19, 20, 21
Learning elements		
A1	Authentic contexts	Qualitative analysis of open-ended questions in the questionnaire as well as reflection in blogs, documentation, facilitator reflections and industry feedback
A2	Authentic tasks	
A3	Expert performances and the modelling of processes	
A4	Multiple roles and perspectives	
A5	Collaborative learning	
A6	Reflection to enable abstractions to be formed	
A7	Articulation enables tacit knowledge to be made explicit	
A8	Coaching and scaffolding by the teacher	
A9	Authentic assessment	

learning environment and societal outputs, such as professional development and learning (Herrington & Reeves, 2011).

Results

Phase 1: analysis of practical problems

In the first phase, consultation with industry partners who participated in the student project during previous years took place. The purpose was to understand their perception regarding the impact of digital innovation on organisations in South Africa, and further the type of skills required by IS students. The aspects highlighted included the development of social intelligence, creative thinking, and an innovative approach to problem-solving. Industry participants valued students who have been exposed to a "real work" environment via, for example, internships or projects in collaboration with the industry.

Six lecturers in the IS department at the University of the Western Cape (UWC) were consulted. They were concerned about the exact meaning and extent of digital skills requirements and how to prepare students for a digital economy. Limitations in the current IS curriculum were also highlighted as an issue to address. The practitioners further expressed their concerns about their practice and how this meets the requirements of a changing landscape.

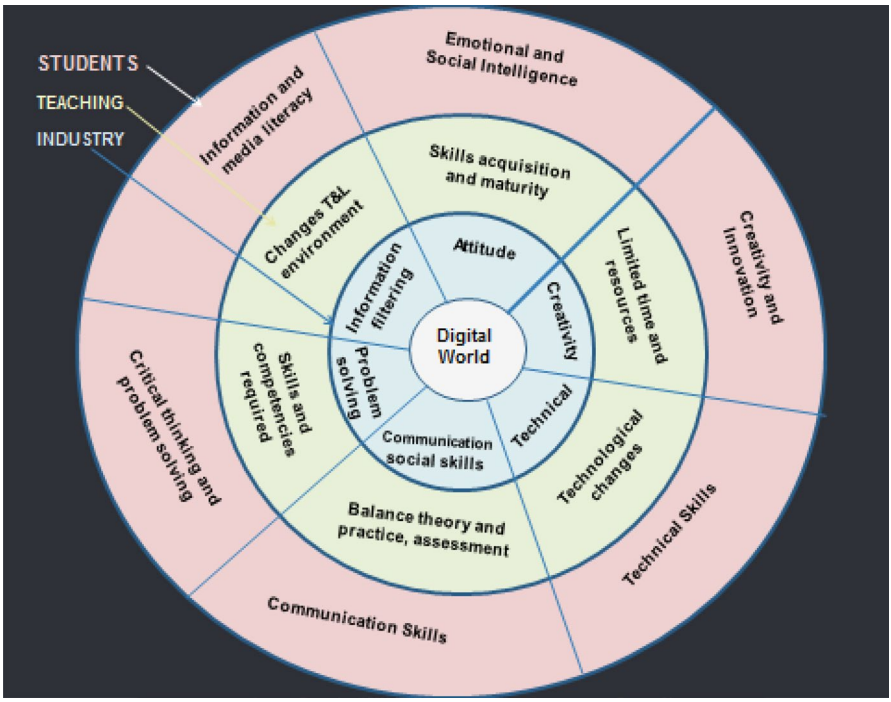

Fig. 3 Challenges identified by students, teachers and industry

A review of student perception related to skills requirements for a digital society took place before the first iteration. The students expressed the need to become more technically flexible. They also expressed the requirement to have more exposure to the industry and work on projects that deal with real-world problems.

The challenges faced by the different stakeholders are depicted in Fig. 3.

Phase 2: draft design principles

The draft principles informed the development of the proposed solution, and the technological affordances identified also formed part of the process for drafting design principles. A mapping of the curriculum design principles to the actual learning environment, including the skill sets and authentic learning elements required (see Table 2), is depicted in Table 4

Phase 3: iterative cycles of testing and refinement

A Design-Based Research (DBR) approach was adopted to enhance the intervention through iterative cycles of data gathering, testing, and verification. After each iteration, the design was refined based on the findings. A review of each draft design principle was conducted by examining the authentic learning elements and skill sets associated with each principle (refer to Table 4) to analyse the outcomes. The analytical approach involved applying quantitative analysis first to test the skill sets acquired by learners (S1 to S8), followed by qualitative analysis to assess the presence of authentic learning elements in the course (A1 to A9). Subsequently, the content presented and the technology applied were analysed to determine the overall outcome of each draft design principle. The principles were updated and refined after each iteration to improve the intervention's overall effectiveness and refine the framework.

Given the extensive data analysis conducted over three years, it is not possible to present the results for each iteration for each section, such as quantitative, qualitative, project artefacts, industry feedback, and facilitator reflections. Instead, the focus will be on the quantitative analysis in iteration 1, the qualitative analysis in iteration 2, and project artefacts and industry feedback in iteration 3. The reflections on how the design principles were reviewed and updated are visually presented for the first two iterations.

Iteration 1

The first iteration took place during a first-semester course with a group of 40 postgraduate IS students. The objectives of the course were the identification, creation and implementation of digital innovation within a client's business (industry partner). Groups could choose clients within the creative industries sector in Cape Town. As stipulated, the quantitative analysis is portrayed for the first iteration followed by the qualitative analysis in iteration 2 and project artefacts and industry feedback in iteration 3.

Quantitative results iteration 1

A regression analysis was conducted to determine the relationships between the variables (skills as indicated in Table 3 coded S1–S9) obtained in the survey results. The regression analysis applied student assessment scores as the dependent variable to test

Table 4 Initial set of draft design principles with authentic learning elements and skills sets

Draft design principle	Application in a learning environment	Skills Codes	Authentic Learning Codes
Encourage collaboration	Students need to perform tasks in teams Ensure that students collaborate to solve problems in class and in projects Use peer reviews	S2, S3	A5, A7
Allow students to find their own solutions	Encourage innovation by letting students take their own initiative Do not put too much structure in place, use some scaffolding when required	S4, S5	A1, A8
Have students produce real products for a real audience	Require students to do a team-based project with organisations within their community where they are required to implement a real solution Work within a specific industry that needs assistance with digital innovation	S5, S6, S7	A1, A2, A3, A9
Use design thinking	This is a structured approach to generating new ideas The stages involve students in discovering a challenge, interpreting the context of the challenge, forming ideas, building prototypes, testing the ideas and developing a solution	S3, S4, S6	A2, A3, A9
Cultivate an interdisciplinary mindset	To understand problems, students need to combine different academic disciplines Innovation requires flexibility; it demands experience and knowledge that is both broad and deep	S1, S3, S8	A1, A2, A3, A4
Encourage reflection	There is usually too much material to cover in too short a time and the tendency is to try to speed things up Allocating enough time for students is necessary to stimulate creativity and innovation	S2, S6, S7	A2, A6, A9
Apply project-based learning	Involve students in projects that are based on real-world, authentic problems that are meaningful and engaging	S1, S3, S6	A1, A2, A9

the importance of the different skills. The analysis tested the reliance on certain skills during an initial assessment and again at the end of the course. The analysis helped to identify the skills that were statistically significant using the p-value to test the null hypothesis. The collected data were analysed using Excel and the Statistical Package for Social Science (SPSS). The quality of results was verified with a hypothesis test where the null hypothesis was all the slope coefficients of the model equalling zero and the attentive hypnosis was that at least one of the slope coefficients is not equal to zero. The hypothesis is rejected if at least one of the independent variables explains the value of the dependent variable by reviewing the p-value. If the p-value is less than the level of significance, the null hypothesis that the coefficient equals zero is rejected; the variable is therefore statistically significant (Anderson, 2014). Typically you would like to produce a high R-value, thus a low p-value with a high R will indicate that the results explain the response variability. However, when one predicts human behaviour, lower R^2 values are acceptable because humans are harder to predict (Anderson, 2014). For this analysis, the p-value, therefore, was examined more closely.

The second statistical test applied was a one-way ANOVA to test the differences between the students' scores for their initial skills survey and the scores obtained for the second survey upon completion of the module. The purpose of one-way ANOVA is to test whether the means of different groups are common or different. The quantitative results are depicted in Table 5 below.

The dependent variable in the regression analysis was student assessment scores using the initial assessments (first blog post, initial presentations and peer reviews) for the first (pre) survey and the final assessments (final blog posts, industry presentations and reports) for the final (post) survey. Table 6 depicts the summary of findings applied to each iteration to review the overall results about skills development.

This process was repeated in each iteration and the results were analysed to review the skill sets that showed an improvement and to highlight areas where further interventions were required. See Table 7 for an example of the review of the multiple regression over the three iterations to show the progress.

The overall findings after each iteration were reviewed and the areas that were deemed to be satisfactory were highlighted in green, the areas that required improvement in amber, and the areas that needed intervention and new strategies in the

Table 5 Quantitative results iteration 1

Skills	Code	Regression P-value		ANOVA	
		Pre	Post	F-value	P-value
Cross-disciplinary	S1	0.050*	0.407	9.47	0.003**
Digital/ICT	S2	0.231	0.701	27.49	1.51E−06**
Communication/collaboration	S3	0.320	0.898	17.94	6.66E−05**
Innovation/creativity	S4	0.117	0.047*	12.06	0.001**
Problem-solving / critical thinking	S5	0.351	0.706	7.98	0.006**
Life/job skills	S6	0.493	0.516	6.09	0.016*
Emotional intelligence	S7	0.152	0.626	5.89	0.018*
Cultural competency	S8	0.437	0.811	3.55	0.06 ns

**$p < 0.01$; *$p < 0.05$; *ns* not significant

Table 6 Summary of skills data obtained iteration 1

Code	Description	Regression	ANOVA	Industry survey	Comments
S01	Core content	1 survey 1	1		Include more design thinking detail upfront
S02	Cross-discipline	2 survey 1	5		Need more evidence of development
S03	Digi/ICT		2	5	The problem for some is more upfront work
S04	Comm/coll		3	1	Good evidence of development
S05	Create/innovate	1 survey 2	4	4	Good evidence of development
S06	Problem/critical		6	3	Need some more evidence
S07	Life/job		7	2	Good evidence of development
S08	EQ/ethics		8	6	Limited evidence
S09	Cultural				No evidence
Comments		Statistical significance of skills in assessments	Rank on F value for skills dev	Rank skills	

Table 7 Multiple regression summary over three iterations

Skills	Iteration 1: P-value		Iteration 2: P-value		Iteration 3: P-value	
	Pre	Post	Pre	Post	Pre	Post
Core content	0.034	0.764	0.325	0.056	0.387	0.048
Digital / ICT	0.231	0.701	0.756	0.747	0.179	0.614
Cross-disciplinary	0.050	0.407	0.003	0.591	0.011	0.330
Communication/collaboration	0.320	0.898	0.410	0.385	0.334	0.939
Problem solving / critical thinking	0.351	0.706	0.814	0.317	0.037	0.009
Innovation/creativity	0.117	0.067	0.803	0.058	0.001	0.0004
Life / Job Skills	0.493	0.516	0.040	0.230	0.430	0.001
Emotional Intelligence	0.152	0.626	0.792	0.452	0.224	0.173
Cultural competency	0.437	0.811	0.639	0.414	0.227	0.004

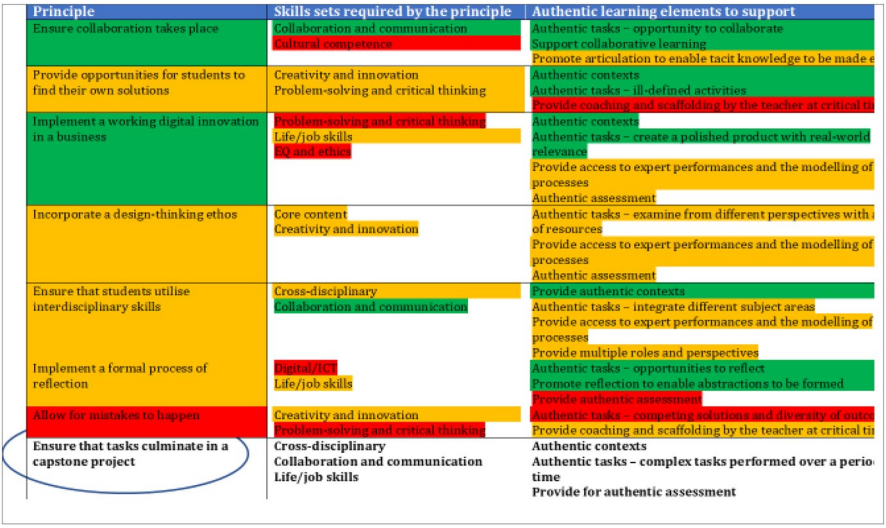

Fig. 4 Outcome of iteration 1 and additional design principle added

following iterations were highlighted in red. These reflections are summarised in Fig. 4 below.

Figure 4 depicts the dashboard applied to summarise the overall outcomes, as seen several areas required further interventions in the following iteration. Only two of the draft design principles were successfully integrated and the following iteration required changes in the design of the projects with industry, the group formation, the assessment of students, coaching and scaffolding and the quality of feedback. After iteration 1, a new principle was added to allow all tasks to be funnelled into a comprehensive capstone project that applies agile methods. The application of Agile allows changes to group formation, regular feedback and the assessment of the overall process and not merely the end solution.

Iteration 2

The second iteration took place during a second-semester course with a group of 42 Information Systems students in their final year. The design of the project changed to incorporate an Agile methodology with clear team roles and regular opportunities for feedback by the facilitator and other teams. The assessments were designed to measure the outcomes per week to allow teams to make changes and improvements. A similar process of data collection was applied. As stipulated, the qualitative analysis is discussed in the second iteration but a similar process was applied to the analysis of the skills as described in iteration 1.

Qualitative results iteration 2

The steps prescribed by Miles and Huberman (1994) to systematically organise the data were applied in the qualitative data analysis. Firstly, data was organised and emerging patterns were identified from the different sources. Thereafter, data was coded about the key pedagogical and design principles identified in the literature and sorted into potential themes (see Table 2). The data analysis phases indicated in the DBR approach were followed through the iterative cycles.

During each iteration, students were tasked to subscribe to a blog and submit three blogs during the semester. The blogs were reviewed to find evidence of authentic learning elements to which the students responded positively in their learning.

The learning environment needs to enhance the ability of students to apply critical thinking to develop the capabilities to become digital innovators. This requires an authentic context (A1) to enable students to apply their knowledge as they would in real life to find their own solutions in the implementation of digital innovations. It also encourages interdisciplinary skills development in the implementation of the capstone project (updated principle). For example:

> *The course was very phenomenal because it teaches about the current issues facing the technological sector and how to improve business processes for an organisation using advance technology.* (LJ2)

However, students also felt that the engagement with industry partners was not sufficient and that their projects were not "real" enough. An area that needed to be redesigned in the next iteration was the type of industry partners with whom students engage. Students ought to be partnered with industry partners that are active in the community for them to see a real change in terms of their digital innovations for example:

> *I would like to suggest that in the next group, the lecturer must identify companies to work with and actually make sure that relations are built beforehand because companies are disinterested in projects that are consultative.* (St23)

Authentic tasks (A2) stimulate collaboration and consist of ill-defined activities that create a polished product with real-world relevance. They are complex and performed over some time to promote competing solutions and a diversity of outcomes. For example, as quoted by a student:

> *I found the incremental steps in developing a product interesting. It made me realise that all the small parts come together to form a product or final solution.* (PG2)

Peer reviews and online feedback were utilised to achieve access to expert performance (A3). During iteration 1, students felt uncomfortable with this and more coaching was done to encourage participation. Students needed guidance on how to give and receive feedback, and this was an aspect that had to be built into the rubric to test the peer review process. Positive outcomes were achieved for example:

> *What I learnt from the exercise was that one does not see their mistakes but quickly notices them in someone else. What I mean by this is that the groups spotted what the other groups did not do or did wrong in their assignments but in actual fact, they also did not do the same mistake but they did not take note of it.* (BN2)

An area in which students felt that they lacked expert performance was particularly their technical ability. Students will need more assistance from experts in the rollout of their projects, particularly in areas in which they are not that comfortable. As remarked by students:

> *More practical sessions to train students more about how to create a website from scratch or through using platforms such as WIX.* (St24)

The provision of multiple roles and perspectives (A4) was explored more during the second iteration to try to encourage students to explore different avenues. More time was spent in class during which students had to work in their teams and analyse their chosen business from different perspectives. They were given a set of questions to answer and present to their peers regarding the industry forces that have an impact on their business, as well as the market forces and key trends that they envisage.

In the second iteration, the creation of a collaborative learning environment (A5) was expanded through the use of Google Drive. This was expressed by a student:

> *What I have noticed and learnt is that this module is presented digitally*
>
> ☺*well I guess it has to be because, after all, it is digital business innovation.* (BN2)

However, group work and collaboration are a challenge and this needs to be monitored throughout to facilitate conflict resolution and teach students the necessary skills to cope in a group environment. As remarked:

> *Put more exercises which focuses [sic] on the individual because I don't think personal development occurs much in group assignments.* (ST2)

The importance of incorporating individual reflection (A6) was stressed in the literature and incorporated into the course from the first iteration. During the first and second iterations, this area was challenging for students as they were not familiar with reflective exercises, but the usefulness thereof was grasped by some students towards the end. This is expressed in the following quotes:

> *I did not enjoy being marked by my peers.* (LJ7)
> *I didn't enjoy doing many self-evaluations.* (St38)
> *I must say, blogging has really made me look deeper into topics and buzzwords in the world of science and technology. And this has for the first time challenged me as a Technology student t think outside the box and share my ideas about the coming future.* (KW2)

Articulation to enable tacit knowledge to be made explicit (A7) was emphasised via regular presentations in class as remarked by a student:

> *The effective presentation and scrum session in class were very fundamental to help me to grow my understanding in the course. I have strong understanding now of how operations of the business function especially how to apply the knowledge from the course.* (LJ18)

The principle of coaching and scaffolding (A8) can be achieved through assessment tasks that facilitate student engagement over time, with feedback generated by various sources. The facilitator needs to carefully coach the teams and put just enough scaffolding in place to enable teams to construct their understanding. It is always a careful balance though as some students need more and others less for example:

> *I wish we had more time with the lecturer, and that she made reference to projects she has done and part-took in, in the past and what she did when she was faced with hurdles and what happens when things do not go according to plan.* (ST2)
> *Lecturer was somewhat repetitive when relaying learning material during group discussions which were distracting*. (BM2)

The utilisation of authentic assessment (A9) is recommended to be integrated throughout the entire assessment process. In the second iteration, assessments were updated with more detailed rubrics to evaluate students on various aspects, such as their collaboration, communication, and content knowledge, at the end of the semester.

Figure 5 presents a summary of the review of iteration 2, following a similar process to that of iteration 1. It was observed that a new design principle was required, emphasizing the cultivation of "social change-makers" who implement digital innovations that benefit both businesses and society, as this was felt to be lacking.

Principle	Skills sets required by principle	Authentic learning elements to support
Ensure collaboration takes	Collaboration and communication Cultural competency	Authentic tasks – opportunity to collaborate Support collaborative learning Promote articulation to enable tacit knowledge to be made explicit
Provide opportunities for students to find their own solutions	Creativity and innovation Problem solving and critical thinking	Authentic contexts Authentic tasks – ill-defined activities Provide coaching and scaffolding by the teacher at critical times
Implement a working digital innovation in a business	Problem-solving and critical thinking Life/job skills EQ and ethics	Authentic contexts Authentic tasks – create a polished product with real-world relevance Provide access to expert performances and the modelling of processes Authentic assessment
Incorporate a design-thinking ethos	Core content Creativity and innovation	Authentic tasks – examine from different perspectives with a variety of resources Provide access to expert performances and the modelling of processes Authentic assessment
Ensure that students utilise interdisciplinary skills	Cross-disciplinary Collaboration and communication	Provide authentic contexts Authentic tasks – integrate different subject areas Provide access to expert performances and the modelling of processes Provide multiple roles and perspectives
Implement a formal process of reflecting	Digital/ICT Life/job skills	Authentic tasks – opportunities to reflect Promote reflection to enable abstractions to be formed Provide authentic assessment
Allow for mistakes to happen	Creativity and innovation Problem-solving and critical thinking	Authentic tasks – competing solutions and a diversity of outcomes Provide coaching and scaffolding by the teacher at critical times
Ensure that tasks culminate in a capstone project	Cross-disciplinary Collaboration and communication Life/job skills	Authentic contexts Authentic tasks – complex tasks performed over a period of time Provide for authentic assessment
Cultivate entrepreneurs with a social conscience	EQ and ethics Cultural awareness	Authentic tasks – competing solutions and diversity of outcomes Provide multiple roles and perspectives

Fig. 5 Outcome of iteration 2 and additional design principle added

Iteration 3

The third iteration took place during a second-semester course with a group of 31 students enrolled in a third-year IS course. After the first two iterations, it became apparent that the students did not learn enough from their industry partners and a different approach to partnering with entrepreneurs in the start-up phase of their business was tried. A start-up phase is more open to change and the opinion was that students would be able to propose initiatives to support digital innovations in the business.

The organisations that the teams worked with included a hair salon that produces natural hair products, a fashion designer, a recruitment agency, a guest house, a quantity surveyor and a winemaker. Table 8 highlights the overview and the results are depicted in (Table 9).

There was an overall improvement in the results obtained from the industry in the third iteration on the conduct of teams. In their engagement with entrepreneurs, the teams were better able to sell the benefits of the digital economy, according to the findings from the last section.

Phase 4: updated design principles

In the fourth phase, the draft design principles developed and updated during the three iterations were updated as portrayed in Table 10. It is important to note that the iterative process that culminated in the final design principles occurred over three years. As noted, the comprehensive data analysis that took place cannot be discussed in a single paper. The purpose of this article is to provide a view of the overall process that can be applied during a DBR study noting that "communicating the processes and outcomes of EDR studies can be challenging because these studies are typically large and complex and because their value to non-stakeholders is not always articulated" (McKenney & Reeves, 2021. p. 89).

Within the study, the students were active participants or co-creators of the research. Ethical approval was obtained and participation in the study was voluntary. The identities of students were protected and there were no risks to them for their participation in the project.

This was a collaborative effort, and much of the insights obtained came from continuous engagement among all the parties involved. Also, the engagement with industry participants required continuous interventions and tweaking of project results. It was not possible to pre-empt any interpersonal issues that occurred in the teams or requirement limitations experienced with the industry partners. The actions taken were different for the different groups and resulted in different reactions. However, it is difficult to gauge whether the positive and negative outcomes were a result of the interventions, or other, external factors.

The updated course design is depicted in Table 10 with more detail about the design principles and a summary of the updated design principles in Table 11.

The updated design principles were implemented in the curriculum design of exit-level IS courses at the university. The principles continue to be tested and refined within the courses. Student projects are now fully interdisciplinary with groups from different universities and different disciplines working collaboratively to implement digital innovations. The student projects also include a strong emphasis on sustainable development goals (SDGs) during the scoping. The application of technology within the learning environment is also continuously updated and refined with a strong emphasis on the different technology tools to enhance interdisciplinary learning in a blended environment

Table 8 Project team outputs iteration 3

Group Name	Client	Project Description	Link to sites developed by groups
BOOM	Lungista's guest house	New website and social media Platforms	https://lungistaguesthouse.wordpress.com/
Digital Intellects	African hair kingdom	New eCommerce website and Social media platforms	http://afropridesa.com
Fantastic Five	Thembela Khuti staffing Services	New website, blog and social media Platforms	https://thembelakuthi.co.za/
On point	Design Twenty-Six	New eCommerce Website	https://design26.co.za/
Young innovators	J9 Wine	New eCommerce website and social media Platforms	https://j9wine.company.site/
Rich guys	Manzi surveyors	Website, digital invoicing, Automated reporting	http://oladipoawopeju.com/

Table 9 Industry feedback questionnaire

	Percentage iteration		
	3	2	1
Questions regarding student conduct			
How well did the group of students engage with you to determine your business needs?	83	78	76
How well did the group of students consult you to analyse your current business model?	78	81	76
What was the quality of feedback received by the group to illustrate your current business model?	78	69	67
How well did the group of students communicate different ideas to improve your business?	89	81	74
How well were you consulted to determine the best idea/s to improve your business?	83	67	74
How well did the group explain the benefits of implementing a digital innovation for your business?	83	81	69
What is the quality of the group's knowledge of your customers?	67	69	71
How well did the group explain different techniques to analyse your customers to you?	72	69	76
How well did the different members of the team work together to implement a solution for you?	83	58	69
How effective was the overall communication and engagement from the students during the project?	72	64	64
Questions on the overall usefulness of new digital innovation implemented			
It helps me be more effective	78	86	81
It helps me to be more productive	78	69	81
It is useful	89	81	81
It gives me more control over the activities in my business	83	78	83
It makes the things I want to accomplish easier to get done	72	78	83
It saves me time when I use it	67	75	75
It meets my needs	83	72	78
It does everything I would expect it to do	83	75	72
It works the way I want it to work	72	69	75
It has been a useful exercise for me	72	67	78
Questions to test the digital savvy of the industry partner			
I am comfortable with my current business model	78	75	62
I am aware of new technologies that can improve my business	78	83	71
I am comfortable adopting new technology in my business	78	78	76
I would like to increase my awareness of potential digital improvements to my business	89	86	81
I believe that I can improve my customer relationship management	83	81	67
It is easy to find technology to support my business needs	72	64	64
The digital economy will have a beneficial impact on my business	89	67	69
My business must become more digitally savvy	83	78	83
As the digital economy grows, so will my business	78	75	76

(van den Berg & Verster, 2022). It is expected that the model will continue to evolve as more practitioners implement it within their teaching and learning environments. One of the purposes of DBR is to circulate information to the broader educational community to inform both theory and practice.

Table 10 Course design

Week	Course content	Assessment
1	Industry Partnership Specification and selection Group Allocation Instruction specifications for online tools and software requirements Introduction to Agile Project Management and Design Thinking	
2	Introduction to Digital Innovation and practical applications thereof to facilitate business model innovation The Business Model Canvass	Individual Questionnaire 1
3	Practical session to prepare current Client Business Models	Team presentations and peer review Individual Blog 1
4	Feedback on Progress Design Thinking: present empathy and define phases Prepare a Co-design workshop for the ideation phase	Presentation of Personas and digital stories
5	Co-design workshop with clients and funnelling of ideas	Decision Matrix
6	Team Presentations Business Model Canvas original and updated to present digital innovation (include all ideas and funnelling of ideas)	Team presentation Business Model and Ideation Individual Blog 2
7 + 8	Practical work session to define prototypes and commence testing	Prepare prototypes
9 + 10	Present prototypes and develop digital innovation artefact	Team presentations
11	Meet with clients to prepare final reports	Show and tell progress meeting and peer review Individual Blog 3
12	Final presentations with clients	Final Presentations Final Report Client Questionnaire Individual Questionnaire 2

Table 11 Updated design principles

Principle	Description and updates
Ensure collaboration takes place	• Students should perform tasks in teams and collaborate to solve problems in class and projects • Online peer reviews that are assessed should be used to encourage collaboration • Within class time, the aim should be to facilitate student learning, rather than being the expert in the room, to encourage experimentation • A blended learning environment should be used to encourage both online and face-to-face collaboration and assess teamwork, work ethic, and collaboration in assessments
Provide opportunities for students to find their own solutions	• Innovation can be encouraged by letting students take their own initiative and by not putting too much structure in place • Scaffolding can be used when required to help students discover their answers by accessing different sources and experimenting with different technologies to become comfortable with pivoting, adapting, and changing • An online community of practice can be created for students to experiment with solutions
Implement a working digital innovation in a business	• Clarify the objectives and scope of the project to keep the project focused and ensure that the team is working towards a common goal • Identify potential industry partners that align with the objectives of the project • Set up clear communication channels between the team and the industry partners • Assign roles and responsibilities to team members to ensure that everyone has a clear understanding of their tasks and what is expected of them • At the end of the project, evaluate the outcomes and assess the project's success against the objectives and scope • Encourage students to think creatively and outside the box. Foster a culture of innovation by rewarding experimentation and risk-taking, while providing a safe space to fail and learn from mistakes
Incorporate a design-thinking ethos	• The design-thinking process involves students in discovering a challenge, interpreting the context of the challenge, forming ideas, building prototypes, testing the ideas, and developing a solution • Agile methodology can be integrated, and clear guidance on the process should be provided • A value-proposition canvas can be used, and students can be guided in the process of empathising with customers via personas and empathy maps

Table 11 (continued)

Principle	Description and updates
Ensure that students utilise interdisciplinary skills	• Combine students from different disciplines in project teams to solve problems or complete projects • Develop coursework that includes interdisciplinary approaches and encourages students to apply their knowledge in diverse settings • Incorporate real-world examples that illustrate how interdisciplinary skills are used in different professions and industries • Assess students' ability to apply interdisciplinary skills by including assessment criteria that test for multiple skills, such as problem-solving, critical thinking, and communication
Implement a formal process of reflection	• Reflection can assist in anchoring learning and stimulating deeper thinking and understanding • The reflection process should be assessed using clear guidance in the rubric in terms of expected outcomes • Experimentation should be allowed, and steps should be built into formative assessments to encourage students to experiment with different solutions
Allow for experimentation	• Provide specific guidance on what types of experimentation are expected, how to document and analyse failures, and how to build upon them to improve future solutions • Create a safe environment for experimentation: Students may be hesitant to experiment if they fear being penalised for failure. To create a safe environment for experimentation, provide clear guidelines on how failures will be evaluated, and emphasise that failure is an expected part of the learning process • Peer review can be an effective way to encourage experimentation. Students can provide feedback to each other on their experiments, helping to identify strengths and weaknesses in their approaches and suggesting alternative strategies • Offer resources and support such as case studies, articles, and examples to inspire creative thinking, and offer support through regular feedback and coaching • Encourage a growth mindset by emphasising that failure is an opportunity for growth and learning. Encourage students to reflect on their experiences, identify what they have learned, and apply those lessons to future challenges

Table 11 (continued)

Principle	Description and updates
Ensure that tasks culminate in a capstone project	• Projects should be based on real-world, authentic problems that are meaningful and engaging • Projects should be structured to be longer-term and interdisciplinary, and students need to provide their structures • Agile methods should be applied, and students should make use of digital tools to produce high-quality end products within a collaborative environment • Assessments should be built to consider the entire process, not just the end product, and allow for multiple solutions
Partner with entrepreneurs	• Entrepreneurial businesses that contribute to their community should be partnered with • A strong emphasis on social awareness and ethical business practices should be encouraged

Conclusion

The digitalisation of society has brought about significant change, with digital innovation being a major driver of transformation. As such, higher education institutions must provide effective, innovative, and high-quality learning experiences that equip students with the necessary skills for a changing labour market. This paper aimed to define the skills requirements of IS students to become competent digital innovators and to develop design principles to teach digital innovation, ensuring industry-informed curriculum design that is future-proof within a digital economy. To achieve this, a four-phased design-based research approach was utilised, and the study was conducted in a South African university, involving students, industry practitioners, and researchers.

The study aimed to answer the research question of how digital business innovation skills should be taught to South African Information Systems students. The findings yielded nine design principles that ensure a future-oriented, industry-informed curriculum design that is relevant to the digital economy. These principles include collaboration, experimentation, the application of design thinking, interdisciplinary problem-solving, regular reflection, project-based learning and industry participation.

This study contributes to the literature by providing valuable insights into the process of articulating validated design principles. However, the study is not without limitations. It was conducted in a single university, limiting the generalisability of the findings, and the study's design and approach may not apply to other contexts or disciplines. Future research should explore the effectiveness of the design principles in other educational settings and examine their transferability across different domains. Ultimately, the study's findings have implications for the development of future-oriented, industry-informed curricula, ensuring that students are equipped with the skills necessary to become competent digital innovators in a rapidly changing digital economy.

Funding Open access funding provided by University of the Western Cape. The study was supported by funding from the National Research Foundation in South Africa. Grant: Support for Completing PhD Studies Part-time 2017 APDS160607168920A.

Declarations

Conflict of interest No potential conflict of interest was reported by the authors.

References

Alexander, B., Ashford-Rowe, K., Barajas-Murph, N., Dobbin, G., Knott, J., McCormack, M., Pomerantz, J., Seilhamer, R. and Weber, N., 2019. EDUCAUSE Horizon Report 2019 Higher Education Edition (pp. 3–41). EDU19. Retrieved 20 October 2021 from https://www.learntechlib.org/p/208644/

Anderson, A. (2014). *Business statistics for dummies*. Wiley and Sons.

Bogers, M. L. A. M., Garud, R., Thomas, L. D. W., & Yoo, Y. (2022). Digital innovation: Transforming research and practice. *Innovation, 24*(1), 4–12. https://doi.org/10.1080/14479338.2021.2005465

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research* (2nd ed.). Sage Publications.

Djankov, S., Saliola, F., Chen, R., Connon, D., & Cusolito, A. (2019). *World Development Report 2019: The Changing Nature of Work: Main Report*. World Bank Group.

Fichman, R. G., Dos Santos, B. L., & Zheng, Z. (Eric). (2014). Digital Innovation As a Fundamental and Powerful Concept in the Information Systems Curriculum. *MIS Quarterly*, 38(2), 329-A15. https://doi.org/10.25300/MISQ/2014/38.2.0

George, D. (2015). Student success kit guide. Retrieved September 7, 2015, from studylib.net/doc/9717312/student-success-kit-student-guide

Goulart, V. G., & Liboni, L. B. (2022). Balancing skills in the digital transformation era: The future of jobs and the role of higher education. *Industry and Higher Education, 36*(2), 118–127. https://doi.org/10.1177/09504222211029796

Herrington, J. & Reeves, T.C. 2011. Using design principles to improve pedagogical practice and promote student engagement. ASCILITE 2011—*The Australasian Society for Computers in Learning in Tertiary Education*. 594–601.

Herrington, J., Reeves, T. C., & Oliver, R. (2010). *A guide to authentic e-learning*. Routledge.

Hevner, A., & Chatterjee, S. (2010). *Design research in information systems: theory and practice* (Vol. 22). Boston: Springer Science & Business Media.

Hevner, A., von Brocke, J., & Alexander, M. (2019). Roles of digital innovation in design science research. *Business & Information Systems Engineering, 61*(1), 3–8. https://doi.org/10.1007/s12599-018-0571-z

Kereluik, K., Mishra, P., Fahnoe, C., & Terry, L. (2013). What knowledge is of most worth? *Journal of Digital Learning in Teacher Education, 29*(4), 127–140. https://doi.org/10.1080/21532974.2013.10784716

McKenney, S., & Reeves, T. C. (2019). *Conducting educational design research* (2nd ed.). New York: Routledge

McKenney, S. E., & Reeves, T. C. (2021). Educational design research: Portraying, conducting, and enhancing scholarship that serves both theory and practice. *Medical Education, 55*(1), 82–92. https://doi.org/10.1111/medu.14280

Miles, M., & Huberman, A. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Sage.

Nambisan, S., Lyytinen, K., Majchrzak, A., & Song, M. (2017). Digital innovation management: Reinventing innovation management research in a digital world. *MIS Quarterly, 14*(1), 223–238. https://doi.org/10.25300/MISQ/2017/41:1.03

Reeves, T. C. (2006). Design research from the technology perspective. In J. V. Akker, K. Gravemeijer, S. E. McKenney, & N. Nieveen (Eds.), *Educational design research* (pp. 86–109). Routledge.

Van den Berg, C. (2019). Teaching innovation to strengthen knowledge creation in a digital world. *Electronic Journal of Knowledge Management, 17*(2), 144–157.

Van den Berg, C., & Verster, B. (2022). Exploring Interdisciplinary Collaborative Online Learning Spaces through Sociomateriality in Cape Town, South Africa. *The Electronic Journal of e-Learning, 20*(4), 467–482. https://doi.org/10.34190/ejel.20.4.2359

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