

Reaping Research Skills from the Rigorous Application of Design Thinking

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Abstract: This paper investigates the relationship between design thinking and the research process, and argues that design thinking can foster the development of research skills. The paper reports on a case where first year Information Systems students apply Design Thinking (DT) in an Internet of Things (IoT) practical assignment. The Hasso Plattner Institute (HPI)'s design thinking process is applied, which entails five phases: empathise, define, ideate, prototype and test. In the Empathise phase, students must collect and analyse data in order to understand user needs. This enables them to arrive at an evidence-based problem definition in the define phase. Later, during the test phase, data is again collected and documented on the user's experience of the prototype. User feedback is then compared with the documented user needs and adjustments are made to address the possible gap. While design thinking is not a conventional research methodology, its use in this manner adds rigour and a scientific base for devising creative solutions. In the group assignment, students were required to document their implementation of the five DT phases by means of a group blog, which was used to assess their projects. While assessing the blogs, the lecturers noted that the students who were more thorough and meticulous in documenting and analysing the user need data, were able to arrive at designs that more appropriately responded to the user's needs. Furthermore, students who provided quotes and/or transcripts of their user interviews, followed by similarly documented feedback during the demonstration and testing of their prototypes, not only convinced that they addressed the real user problem, but the rigour they applied facilitated more innovative designs. This was an interesting finding, because the innovation itself is usually associated with the creative phases (ideate and prototype) rather than the empathise and test phases. This paper argues that when applying DT in a rigorous manner, students are enabled not only to produce better designs, but they also gain valuable research skills for their future benefit.

Keywords: Design Thinking; Future of Work; User Needs Analysis; Research Skills; IoT group assignment

1. Introduction

The skills required for the future world of work are receiving increased attention. According to the World Economic Forum, the top skills that will be required by 2025 include analytical and critical thinking, innovation, complex problem-solving, reasoning and ideation (World Economic Forum, 2020). In the field of Information Systems (IS), critical thinking and problem-solving are recognized as foundational skills in the international undergraduate IS curriculum (Topi et al., 2010). To this end, the first year IS students at a South African university have a course focusing on critical thinking and problem-solving as part of their degree programme. The problem-solving component of the course covers analytical problem-solving as well as creative problem-solving. Creative problem-solving is taught by introducing students to the Hasso Plattner Institute's (HPI) design thinking process (Hasso Plattner Institute of Design at Stanford, n.d.). As part of the course, students are required to do a group assignment where they design and build an artefact using design thinking. While assessing the students' deliverables, the lecturers noted that the students gained more than just creativity and design skills. The student projects also benefited from the rigorous investigations they undertook to understand and document their user's needs, and the efforts that went into interpreting these needs to respond to them appropriately. This meant that the students also gained valuable research skills, since research is about a systematic inquiry that involves collecting, analysis and interpretation and reporting of data to the satisfaction of users (Mertens, 2019; Oates et al., 2022). After the lecturers personally noted how some students' final deliverables benefited from a rigorous investigation into their user's needs, it was decided to perform a case study to investigate whether this trend applied more generally across the student group. Hence, a research study was scoped around the class of 2022's student group projects. The study was guided by the following research question:

- *How does the application of design thinking assist first year Information Systems students to develop research skills? (Research skills refer to the skills needed to perform a systematic inquiry where one needs to collect, analyse, interpret, and report on data).*

This paper reports on the study that was undertaken to investigate the above research question. The rest of

the paper is organised as follows. In the next section, background literature is provided on design thinking and research skills. Thereafter, the case study is described in the research method section. Following this, the data analysis is presented, along with a discussion and interpretation of the findings. The paper ends with concluding remarks and suggestions for future research.

2. Background

This section covers background on design thinking, the research skills required by university students as well as the complementary relationship between design thinking and research skills.

2.1 Design thinking

Design thinking is an iterative, human-centred, problem-solving approach (Interaction Design Foundation, n.d.). It focusses on empathising with the user, user collaboration, ideation, and swift prototyping to create innovative solutions to ill-defined messy problems (Brown, 2009). It combines analytical and intuitive thinking and integrates the needs of people with the possibilities offered by technology (Hasso Plattner Institute of Design at Stanford, n.d.).

Different design thinking models which consist of three (IDEO, n.d.), four (Aalto University, 2016; Design Council, n.d.; Singapore Polytechnic, 2016) or five (Hasso-Plattner-Institute, n.d.; Stanford University Design Institute, n.d.) phases, and which are presented by design schools (Aalto University, 2016; Hasso-Plattner-Institute, n.d.; Singapore Polytechnic, 2016; Stanford University Design Institute, n.d.) and enterprises or organisations (Design Council, n.d.; IDEO, n.d.), exist. The HPI design thinking process is the one which students are taught in their first year IS course on critical thinking and problem-solving. This five-phase process involves empathising with users, defining the problem, ideating solutions, prototyping, and testing (Brown, 2009). The first phase involves understanding the needs and behaviours of the users. The focus is to gain an in-depth understanding of the problem. This step is essential as it allows designers to identify the root cause of the problem and to develop a solution that fulfils the needs of the users. The second phase is to define the problem with a clear and actionable problem statement. This phase is crucial as it sets the foundation for the design thinking process to follow. The third phase is ideation. During this phase numerous creative ideas are generated which could address the user's needs. The fourth phase, prototyping, involves the creation of a physical or digital representation of the chosen idea(s). This phase allows designers to test the solution and gather feedback from users to improve it. The focus of the prototype is not on selling the solution, but rather on showing it to the user to elicit feedback. The final phase, testing, involves testing the solution with users and refining it based on their feedback.

Liedtka (2015) describes the contemporary design-thinking process as a process driven by a hypothesis, focussing on both the problem and the solution. It is based on abductive reasoning and experimentation with several alternative solutions (and their constraints) which propose different possibilities in a contest to be chosen as the best option in an uncertain and ambiguous context. Iteration, re-thinking and learning through experimentation form central tasks in this process.

Design thinking has broad applications across various fields. Its ability to drive innovation, improve outcomes, and enhance user experiences has made it an attractive approach for businesses (Cagnin, 2018), healthcare (Smiechowski et al., 2021) and education (Stock et al., 2018). It has also been widely applied to address complex social problems and to improve the lives of individuals and communities (Chou, 2018).

2.1.1 *The benefits of design thinking*

One of the primary benefits of design thinking as a problem-solving approach is its ability to drive innovation (Brenner & Uebernickel, 2016). Design teams are encouraged to think outside the box, to challenge assumptions (Pontis & Van der Waarde, 2020) and to experiment with new ideas (Liedtka, 2011). Another benefit is the emphasis which design thinking places on collaboration and teamwork (Nguyen et al., 2021) which results in sounder innovations and in bringing people from different skill sets together. As design thinking places a strong emphasis on empathy during the needs discovery process, implementers succeed in meeting the needs of their users more effectively (Gasparini, 2015). Design thinking encourages experimentation with new ideas and solutions, even if outcomes are uncertain. This fosters a culture of experimentation which encourages teams to test and iterate their solutions until they reach the best possible outcome (Carlgren et al., 2016).

2.2 Research skills

In short, research refers to “a process of systematic inquiry that is designed to collect, analyse and interpret data” (Mertens, 2019). Oates complements this definition by focusing on the outcome of research: “Research is the creation of new knowledge, using an appropriate process, to the satisfaction of the users of the research” (Oates et al., 2022). According to Myers (2019), the research process of generating new knowledge is a creative activity.

2.1.2 Research skills required by IS graduates

At this stage, we first need to step back to gain an overall understanding of what is required of an IS graduate. An IS graduate is expected to have a sufficient understanding and knowledge of both the business or organisational environment and the information technology domain, in order to develop innovative information systems solutions to the benefit of the organisation (Topi et al., 2010). The skills required to perform this task include business analysis skills, a variety of technology skills as well as a set of soft skills that includes *inter alia* problem-solving skills. Where do research skills then belong, within this skill set? Several IS scholars regard a focus on research skills to be more relevant on a postgraduate rather than an undergraduate level (Lamp et al., 1996; Snoke, 2004).

Typical skills needed to perform proper scientific research on postgraduate level include: problem identification and creative thinking skills (to identify research questions or problems and to formulate a hypothesis); reading skills (to conduct a literature review on the research topic); critical thinking skills (to critically review and evaluate and synthesise information from various sources); research design skills (to choose an appropriate research methods); data collection skills; data analysis and problem-solving skills (using appropriate statistical or qualitative methods to analyse data); interpretation and synthesis skills; and documenting, writing and communication skills (Oates, 2022).

At undergraduate level, research skills are often grouped together with the basic information or media literacy skills (Reif et al.). However, Reif et al. (2005) claims that such a view disregards the important connection between research and problem-solving skills, the latter which is a foundational skill for IS graduates. Reif et al. (2005) compares the research and problem-solving processes step by step, showing that they are essentially the same. According to Reif et al. (2005), enhancing students’ research skills at undergraduate level provides far more than media literacy; rather, enhances their skills of problem-solving, critical thinking as well as creative thinking.

2.3 Relationship between design thinking and research

When we consider the definitions of research given above, as well as the claims of Reif et al. (2005), the links between design thinking and research are evident. Both are problem-solving processes and require: a deep understanding of the problem context at the onset (whether obtained by means of investigating the literature or studying the needs of a user); a focused problem statement to guide the investigation so as to arrive at meaningful results; a thorough search through available options to address the problem; and an iterative mode of working where possible outcomes are assessed against the original problem statement. Both scientific research and design thinking make use of hypotheses (educated guesses about the nature of a phenomenon or problem), although these hypotheses differ in their purpose, scope, and testability. Scientific research hypotheses aim to generate new knowledge and advance scientific understanding, while design thinking hypotheses are used to guide the ideation and prototyping processes (Liedtka, 2015). Whereas design thinking is perhaps better associated with creativity, research is equally known for its role in innovation. In this study, we argue that when design thinking is approached with requisite rigour, such as when applying the HPI design process (Hasso Plattner Institute of Design at Stanford, n.d.) it simultaneously contributes to the development of good research skills.

3. Research method

To respond to the research question, a case study was scoped around the student class of 2022’s group assignment projects. A descriptive case study was performed (Maree, 2007), with the 2022 student group forming a single case. The study followed an interpretive research philosophy, where the focus was on understanding an occurrence within its natural social setting (Oates, 2022). In the sections below, the case is described in more detail, followed by the data collection and analysis process.

3.1 Case description

The case consisted of the group of first year students enrolled for a course in critical thinking and problem-solving, as part of studying a three-year degree in IS at a South African university. There were 244 students enrolled for the course which was presented in the first semester (January to June) of 2022. Under the problem-solving component of the course, students were taught design thinking as an unstructured problem-solving approach. Their main project under this theme was a group assignment for which they had to form self-selected groups of 4-6 students. According to the assignment task, each group had to: "...design and build a prototype of a home automation device, using the design process of the Hasso Plattner Institute. The prototype must use microcontroller technology such as micro:bit, Arduino or Raspberry Pi. Your client (for the empathise phase) will be a homeowner of your choice. The product needs to be a consumer product for a household, garden or pets. For the prototype and test phases, you will need to demonstrate a tangible working prototype."

Forty student groups were formed. Each group had a blog space on the university's Learning Management System (LMS) where they had to provide evidence of their execution of the empathise, define, ideate, prototype and test phases. For the 'empathise phase', students had to provide evidence of an interview with their user (a homeowner). They had to supply a well-focused problem statement (one sentence) for the 'define phase' and 3 - 5 possible designs for the 'ideate phase', after which they had to upload a video demonstrating a working prototype, for the 'prototype phase'. Lastly, they had to supply 2 - 3 user quotes as proof of the feedback they received from their user during the 'test phase'.

3.2 Data collection and analysis

The data that formed part of the study was the information contained in the student blogs, as well as the student marks. Groups received a mark for each phase, as well as an overall mark. The marks were analysed quantitatively and the blogs qualitatively to address the research question. The lecturer who marked the assignments was not part of the research team, to reduce bias.

4. Results

Statistical analysis was conducted on two sets of data using IBM SPSS Statistics Version 28.0.1.0 (142). The first set of data pertains to the outcomes of the 40 student groups and the second set to the overall outcomes of the 244 students enrolled for the module. The purpose was twofold: to determine how design thinking can be used to support scientific inquiry; and whether the group assignment impacted other outcomes within the module.

4.1 Group outcomes assessment

Descriptive statistics pertaining to the assessment of the 40 student groups is shown in Table 1. Standard deviation measures within the dataset shows that the 'test' phase was the most spread, indicating that groups had widely varying success in this phase. Reasons for this could be students' deficient technical ability to test concepts in the field, or ineffective time allocation by the groups to complete the last phase of their assignment. 'Prototyping' was spread as well, albeit to a smaller degree, demonstrating that the groups delivered varying results as they progressed through the phases. Within the prototype phase, this could be attributable to their inability to effectively adopt technology to build a prototype, a lack of time allocated, or their inability to prioritise what could address their defined problem.

Table 1: Descriptive statistics of group results. Source: IBM SPSS

Stage of design thinking	N	Minimum	Maximum	Mean	Std. Deviation	Kurtosis	Std. Error
EMPATHISE	40	6.00	10.00	7.93	1.071	-.971	.733
DEFINE	40	4.00	10.00	6.50	2.253	-1.110	.733
IDEATE	40	.00	10.00	7.60	1.959	4.591	.733
PROTOTYPE	40	.00	10.00	7.95	2.470	6.488	.733
TEST	40	.00	10.00	6.60	3.241	-.209	.733

This is supported by the Kurtosis indicator, where prototyping showed a wide distribution. However, empathise and define was negative. Consequently, the collection and ability to understand problems was closely clustered, demonstrating that the design thinking approach provided a way for students to collect data on and understand the user problem in a scientific manner, as well as define it properly. The standard error is a precision estimate, showing that a 0.7333 sampling error can be expected.

The analysis focused on the results within the design thinking phases and their overall impact on the success of the approach. To provide a clear visualisation of these findings, Figure 2 illustrates how the results within the design thinking phases were overall positive for the 40 groups assessed. The figure highlights the significant impact that the prototyping and testing phases had on the success of the approach and provides valuable insights into the effectiveness of design thinking as a teaching method in promoting positive outcomes among students.

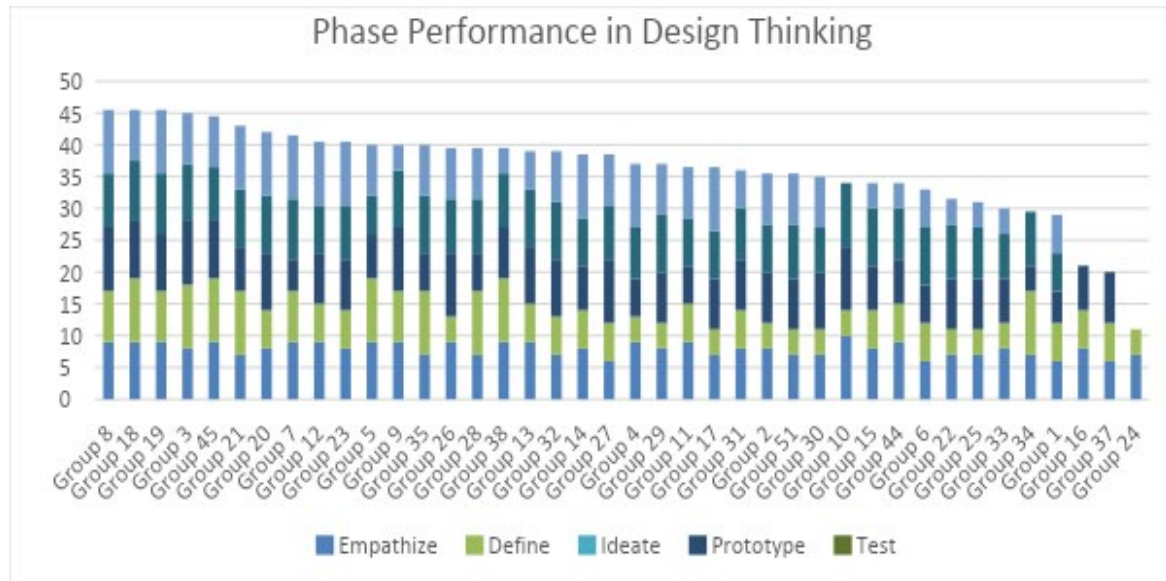


Figure 1: Overall group performance to deliver creative outcome

Using the analysis of variance (ANOVA), the results support the fact that students who were more thorough and meticulous in documenting and analysing user need data (done during the empathise phase) were able to arrive at designs that more appropriately responded to their users' needs. This finding is consistent in that user-centred design processes, which rely on careful observation, documentation, and analysis of user behaviour and feedback, are critical for developing effective and innovative designs. In particular, the results suggest that students who provided evidence of user interviews, followed by similarly documented feedback during demonstration and testing of prototypes, were more successful in convincing others that they had addressed a real user problem. This rigour not only facilitated more innovative designs but also increased the credibility of the design solutions in the eyes of the users. In the context of using design thinking as a teaching method, the ANOVA outcomes revealed valuable insights into the success of the approach. Specifically, the sum of squares (SS), which represents the variability in the dependent variable that is accounted for by each independent variable, was found to be influenced significantly by the prototyping and testing phases within the groups. Mean squares (MS) that represent variance accounted for by each independent variable supports this at 0.762 within groups. However, the test phase at 3.048 within groups shows that the final outcome was significantly different amongst groups through the iterative process. Moreover, the F-value (f) that represents the ratio of variance explained by the independent variable to the variance not explained by the independent variable, shows that the prototype and test phases at 11.93 and 4.86 respectively varied the most. This suggests that the design thinking process, which emphasises iterative steps, was successful in developing research skills such as obtaining information to understand problems. However, the last phases differed, where the group's ability to develop a prototype and test varied significantly. This could be due to the reasons mentioned before.

4.2 Group marks that correlate to individual success

Factor analysis was used as an exploratory technique to uncover any underlying structure of the dataset where 244 students' outcomes were assessed to identify patterns of intercorrelations among the observed variables.

While processing the analysis of results of group outcomes to individual success, several assumptions were made including that (1) there are no outliers, (2) there was a sufficient sample size (>200), (3) no perfect multicollinearity exists and (4) all data is interval data. All factor scores were above 0.7 representing that the factors extracted sufficient variance, in this instance the group assignment. To determine if the data was suitable for factor analysis, the Kaiser-Meyer-Olkin (KMO) test was used as it is a measure of sampling adequacy. Values range between 0 and 1, with values closer to 1 indicating better suitability for factor analysis. An acceptable value for the KMO test is typically considered to be above 0.6. In this instance 0.642 was achieved. Moreover, the Bartlett test was used to assess the homogeneity of variances across different groups or samples. An acceptable result for the Bartlett test is a low p-value, typically less than 0.05. In this instance it was significant at <.001. Consequently, a one-tailed hypothesis test was deemed appropriate. This tested for significance in only one direction because it allowed for a more focused testing of the specific direction of the effect, rather than testing for any significant difference, regardless of direction. Overall, the group assignment shows to have significantly impacted individuals' ability to not only factor in scientific analysis, but also improve their overall examination capabilities and understanding of the subject material as shown in Table 2.

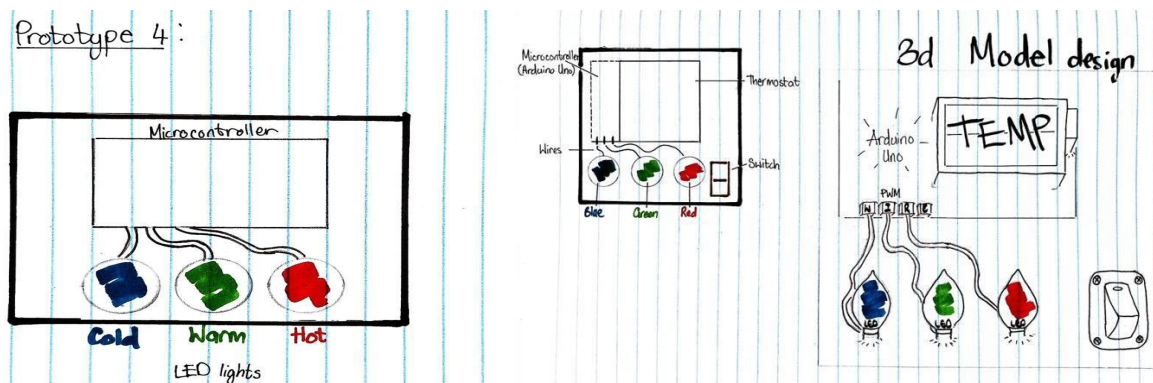
Table 2: Factor analysis of design thinking as a teaching tool. Source: IBM SPSS.

		DTGROUP	SM	ST	EXAM
Correlation	DTGROUP	1.000	.654	.191	.382
	SM	.654	1.000	.704	.679
	ST	.191	.704	1.000	.479
	EXAM	.382	.679	.479	1.000
Sig (1-tailed)	DTGROUP		<.001	.001	<.001
	SM	.000		.000	.000
	ST	.001	.000		.000
	EXAM	.000	.000	.000	

4.3 Qualitative data where the iterative design process was used

The findings suggest that the level of rigour displayed by the groups was a key factor in their success in applying systematic inquiry within the design thinking process. Specifically, those groups that demonstrated a higher level of rigour were able to articulate their inquiry in a more systematic manner and apply it more effectively throughout the different phases of the process. These patterns were evident in the clustering of groups within each phase of the design thinking process. However, when groups deviated from the process and displayed a lower level of rigour, the distribution of their results became more widely spread, as seen in Figure 1 and supported by the ANOVA analysis. Below is a snapshot of a successful group who followed the iterative process.

Group 8 developed a device to monitor the temperature of a geyser. One of their prototype feedback quotes included "As a stay-at-home mom I must say that the device has helped save quite a significant amount of electricity since the different colour lights notify me when I should turn the geyser on and off. Also, the device displays the temperature, that is a great addition. Electricity wastage is totally being eliminated!!". Their process and outcome are shown in Figure 3.



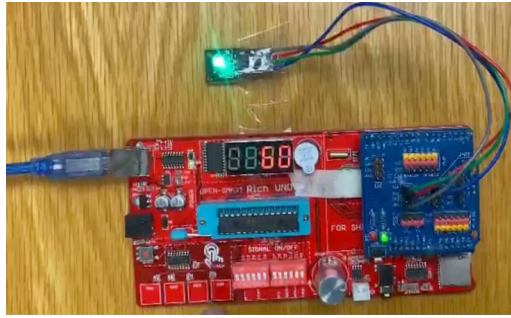


Figure 3: Group 8 documentation and research analysis to develop a solution.

5. Discussion

The first two phases of the design thinking approach followed by students were ‘emphasise’ and ‘define’ (Hasso Plattner Institute of Design at Stanford, (n.d.)). These two phases have underlying cognitive processes of exploration and generation (Stempfle & Badke-Schaub, 2002) and require the designer to understand the needs and behaviours of the user, to gain an in-depth understanding of the problem, and to define the problem with a clear and actionable problem statement (Brown, 2009). The findings show that students were able to handle these two phases comfortably and that the design thinking approach equipped them with skills to collect data to understand their user’s problem in a scientific manner, and to define their user’s problem properly. Furthermore, groups who were more thorough and meticulous in documenting and analysing their user need data, by providing quotes and/or transcripts of their user interviews, were able to arrive at designs that more appropriately responded to their user’s needs. The groups in general seemed to struggle more with the last phases of the design thinking approach, which have underlying cognitive processes of comparison and selection (Stempfle & Badke-Schaub, 2002), and which requires the groups to select, develop and test the most suitable prototype, varied significantly. This could be due to the students’ inability to effectively adopt the IoT technology to build their prototypes (for many of them it was their first encounter with this technology) or their inability to manage their time, leading to them rushing through the last two phases in an attempt to finish their assignment on time. Important to note is that the results do show that students who provided evidence of their user interviews, followed by detailed documented feedback during the demonstration and testing of their prototypes, were more successful in convincing others that they addressed the real user problem. As the steps with which the students were successful point to the application of problem identification, creative thinking, data collection, documenting, writing, and communication skills, which are all considered to be important research skills (Oates, 2022), the findings suggest that the design thinking approach taught to undergraduate students as a problem-solving approach to tackle ill-defined messy problems, seems to have cultivated and fostered important research skills.

6. Conclusion

The aim of this paper was to argue that teaching the design thinking approach to problem solving, fosters better research skills for undergraduate IS students. The study was guided by the following research question: *How does the application of design thinking assist first year Information Systems students to develop research skills?* A descriptive case study was carried out, centred around a design thinking group assignment performed by 244 first year South African Information Systems students, as part of a critical thinking and problem-solving course. In the preceding literature review, a strong alignment was found between research and design thinking. In particular, the HPI design process requires a thorough investigation into user needs, involving data collection, analysis and interpretation. The findings of the empirical study showed that design thinking equipped students with skills to collect data to understand their user’s problem in a scientific manner, and to define their user’s problem properly. It further showed that groups who were thorough and meticulous in documenting and analysing their user need data, were able to arrive at designs that more appropriately responded to their user’s needs. While some groups struggled with the practical prototyping and testing of their designs, where various external factors started playing a role, the HPI process at least provided them with good guidance to perform well in the earlier phases which was where research-like activities were required. These findings have important implications for design education and practice. They suggest that designers who invest time and resources in carefully documenting and analysing user behaviour and feedback are more likely to develop successful and innovative designs. Additionally, these findings highlight the importance of teaching design

students to engage in user-centred design processes and to prioritise user needs in their work.

This study was limited to a single descriptive case of a first year Information Systems class in South Africa. Future research can entail repeating the study with more detailed hypothesis, as well as requiring from students to reflect on their own learning during similar assignments. The continuation of this project holds many possibilities for research and practice, showing how fostering of the skills base underlying both research and design, can contribute to building innovation and problem-solving skills that are essential for the future world of work.

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