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# Fostering Critical Thinking Skills in Higher Education: The Impact of Student-Built Dashboards

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**ABSTRACT**

Given the rapid changes in the employment market as well as more demand for higher-level thinking skills in jobs, university programs are required to develop students' industry-relevant skills. One of the most important skills is critical thinking, which is hard to find in graduates. This study aimed to examine whether teaching students how to design and build dashboards, which served as an experiential learning tool, fostered their critical thinking skills over the course of four years. It also investigated students' and instructors' perceptions about implementing student-built dashboards. A design-based research approach was employed whereby quantitative and qualitative data were triangulated. The quantitative data were collected from students' performance on summative tests before and after implementing dashboards with appropriate training. The qualitative data regarding student and staff perceptions about implementing student-built dashboards were obtained using a survey and a semi-structured interview, respectively. The findings indicated that students' performance on the final assessment, which mainly targeted their critical thinking abilities, was enhanced compared to the previous semesters. The results of the satisfaction survey also suggested that learners were highly satisfied with the unit and benefited from dashboards. Moreover, the interviews with staff revealed that they also favoured using dashboards as they increased students' critical thinking and higher-order thinking abilities. This study unravels the potential of student-built dashboards to foster students' critical thinking and increase graduates' employability, thereby implicating educators to teach and assess dashboard design.

**Keywords:** Experiential learning & education, Critical thinking, Dashboards, Industry-relevant skills

## 1. INTRODUCTION

The employment market and the nature of work are rapidly evolving as we navigate the Fourth Industrial Revolution (World Economic Forum, 2018). These changes are driven by globalisation, technological advancements, and external pressures such as shifting government policies, global tensions, climate change, and the impact of COVID-19 on the workplace. Consequently, employers now require new or more advanced skills from those entering and navigating the employment landscape. Jobs demanding higher-level thinking skills are expanding at the expense of routine-based positions, with companies estimating that half of all current employees will require upskilling (Department of Jobs and Small Business, 2019). Employers expect graduates to be "work-ready" upon employment and learn quickly in their new roles (Australian Business Deans Council, 2023; Spanjaard et al., 2018). Therefore, the responsibility lies with educators to develop

industry-ready skills and capabilities in students to meet the current and future needs of graduates and employers. Since the early 2000s, universities have recognised the need to align their curricula with employer requirements (McArthur et al., 2017). Discussions around the necessary graduate skills – both academic and non-academic – often highlight the importance of a combination of well-developed technical (hard) skills relevant to a discipline, as well as well-developed transferrable (soft) skills (Daellenbach, 2018). Among these, critical thinking skills are paramount.

Critical thinking is considered vital in modern workplaces where careers are increasingly analytical and knowledge-based (Erikson & Erikson, 2019; Moore, 2013; Nentl & Zietlow, 2008; World Economic Forum, 2018; Yeoh, 2019). Yet, employers have identified critical thinking as one of the most challenging skills to find in candidates (Agrawal et al., 2018). There is a consensus that enhancing critical thinking skills in students requires greater attention and emphasis in higher education (Dahl et al., 2018; Lovelace et al., 2016; Shaw et al., 2019). As it is the role of higher education to teach the skills required in the modern workplace (Tholen, 2019), the question remains: *How can these skills be taught more effectively?* (Behar-Horenstein & Niu, 2011; Glen et al., 2014; Puig et al., 2019). Teaching critical thinking is challenging partly because there is no universally accepted definition of what "critical thinking" entails (Moore, 2013). This ambiguity creates a gap in knowledge surrounding how to teach critical thinking to students, calling for more attention in higher education (Dahl et al., 2018).

Several approaches have been suggested to improve students' critical thinking capabilities, such as teaching students how to conduct high-quality secondary research (Nentl & Zietlow, 2008) and using visualisation tools such as concept maps (Young, 2005) and graphics (Athanassiou et al., 2003; Saundage et al., 2016). One approach that integrates all these methods is teaching students how to create dashboards to collate, manage, and interpret data and information. A dashboard is a tool widely adopted in the industry that brings together diverse information from multiple sources into a single visual display to analyse changes and aid decision-making (Grewal et al., 2018; Schlee & Karns, 2017). This research examines the process of enhancing critical thinking capabilities using student-created dashboards. Specifically, it aims to assess the impact of student-built dashboards on students' critical thinking skills and to investigate both students' and staff's perceptions of this instructional method.

## 2. BACKGROUND

### 2.1 Critical Thinking and Experiential Learning

Critical thinking is a multifaceted concept that has resisted an exact definition due to variations across authors and fields of study (Erikson & Erikson 2019; Shaw et al., 2019). Ennis (1987) describes critical thinking as "reasonable reflective thinking that is focused on deciding what to believe or do" (p. 10). Similarly, Kurfiss (1988) defines it as "an investigation whose purpose is to explore a situation, phenomenon, question, or problem to arrive at a hypothesis or conclusion about it that integrates all available information and that can therefore be convincingly justified" (p. 2). It encompasses a wide range of abilities, from the ability to think scientifically within a discipline, utilizing discipline-specific skills, to the broader skills and ability to critically reflect on personal experiences and the world at large (Erikson & Erikson, 2019; Pithers & Soden, 2000). While critical thinking has long been central to educational outcome, it has recently become a highly sought-after skill in both academia and industry, underpinning students' preparation for post-secondary education and the workforce (Hamilton & Klebba, 2011). There is an ongoing debate in the literature about whether critical thinking can be taught or whether it is a developmental process (Goodsett, 2020).

Fostering critical thinking requires an effective learning taxonomy. Bloom's Taxonomy, widely used in curriculum design, is accepted as a platform for developing critical thinking skills (Dahl et al., 2018; Wilson et al., 2018). This taxonomy views learning as a linear process occurring in six successive stages: knowledge, comprehension, application, analysis, synthesis and evaluation (Bloom & Krathwohl, 2020). However, many educators find it challenging to use this model to move students from the foundational stages (knowledge, comprehension, application) to the higher-order critical thinking stages (analysis, synthesis and evaluation) where students acquire knowledge and organise and integrate thoughts (Athanassiou et al., 2003; Dahl et al., 2018; Kachouie et al., 2024; Nentl & Zietlow, 2008).

An alternative approach to fostering critical thinking is through experiential learning – "the process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 38). Originating from the works of Dewey (1938), Piaget (1952), and Lewin (1957), and further developed by Kolb (1984, 2014), experiential learning supports learning by engaging learners in the course of action. This engagement provides a basis for fostering critical thinking because it results from learners' active involvement with complex issues (McCarthy, 2016; McCormick, 1993). Specifically, critical thinking can be conceived as a by-product of learners' active engagement with complex environmental issues that necessitate experiential learning.

Kolb's (1984) framework provides a foundation for understanding how students interpret experiences and transform them into meaningful knowledge (Javadi et al., 2025). According to Kolb (1984, 2014) and Kolb and Kolb (2005) learning is best seen as a process not an outcome, and the most effective learning occurs when a learner goes through the four phases of the learning cycle: experiencing, reflecting, thinking, and acting, which can be described as concrete experience, reflective observation, abstract conceptualisation, and active experimentation (Kolb, 1984). Within this cycle, Kolb (1984, 2014) proposes that knowledge results from the combination of grasping and transforming experiences. The main underpinning of this model is the creation of knowledge through the transformation of experience (Young et al., 2008; Wilson et al., 2018). Through this process, higher-level learning occurs when students move beyond knowledge creation and apply knowledge to solve problems and develop solutions (Kolb & Kolb, 2005).

There are numerous activities for fostering critical thinking through experiential learning including on-the-job training (Robinson et al., 2010), structured and complex case studies (Adler et al., 2004; Klebba & Hamilton, 2007; Rippin et al., 2002), role-plays, and simulations (Farkas & Shang, 2024; Thouin & Hefley, 2024). Studies examining the contributions of experiential learning to fostering critical thinking have been

conducted in different disciplines and at different educational levels. Voukelatou (2019) investigated the effects of project-based teaching, an experiential learning approach, in a secondary school in Greece. The results indicated that experiential learning had a significant impact on learners' development of social skills, including critical thinking abilities, as well as their understanding of cultural heritage. In the context of nursing, Seibert (2021) focused on the higher-order critical thinking abilities of Generation Z, indicating that despite their high level of competence in technological skills, Generation Z tends to give up in the face of challenges. Having scrutinized the features of problem-based learning, experiential learning, and critical thinking, Seibert (2021) concluded that an interaction exists between them. In other words, she suggested that problem-based learning and experiential learning have a striking benefit for critical thinking. In an experimental study, Mustafa et al. (2022) examined the effectiveness of experiential learning on nursing students' critical thinking as well as their attitude towards nursing. Their findings indicated that experiential learning afforded increased levels of critical thinking. Besides, it improved learners' attitudes towards the nursing profession.

Given the potential of experiential learning to enhance critical thinking, one promising approach can be using student-built dashboards as interactive, data-driven tools. Dashboards require students to engage in hands-on learning, applying critical thinking skills to collect, analyse, and visualise data. While dashboards have been widely used in business and data analytics, their role in fostering critical thinking as an experiential learning tool remains underexplored. The following section elaborates on educational applications of dashboards, highlighting their potential as a pedagogical tool for cultivating critical thinking.

### 2.2 Dashboards

The use of dashboards to present data is not new; industries like automotive and aviation started using dashboards to show performance data about a century ago. Dashboards are defined as "complex systems which interact with or incorporate data storage architectures, state-of-the-art algorithms for query management, information retrieval and visualization, as well as a suite of user-oriented features which provide flexibility through personalization and adaptation to various professional contexts" (Zhuang et al., 2022, p. 1715). They are designed to present a range of collated and analysed data relevant to a specific field, topic, or problem, leading to conclusions, insights, and decision-making. Parallel to the developments in statistics and economics, dashboards have evolved to become widely adopted in commercial sectors as platforms that consolidate information from multiple sources into a defined visual display, aiding decision-making and tracking changes (Grewal et al., 2018; Schlee & Karns, 2017). Typically, dashboards present a mixture of analysed and current data, supported by a technology interface and a set of algorithms or analytical logic. Within the educational field, dashboards are increasingly used by educators to teach analytics and support decisions about students' learning, engagement, and improvements (Klein et al., 2019). To date, students' exposure to dashboards has been primarily as a tool for tracking personal progress and for reflection (Robinson et al., 2010).

Using dashboards in educational contexts has been the subject of several empirical studies. Recognising that business analytics capabilities are valuable and provide a competitive advantage for organisations, Rivera and Shanks (2015) examined how the management of such capabilities can be supported. They developed and evaluated a dashboard to assess business analytics abilities. Their findings indicated that business analytics alone might not constitute an asset to organisations; instead, organisations must enhance their infrastructure by supporting dashboards, which ultimately lead to the successful management of business analytics capabilities. Molenaar and Knoop-van Campen (2019) studied teachers' use of dashboards in mathematics classes, examining how teachers consulted dashboards and observing the ensuing pedagogical actions in the classroom. Their findings suggested that teachers consulted dashboards about eight times per lesson, resulting in the provision of individual feedback and additional instructions. It was concluded that dashboards affect teachers' pedagogical practices and trigger changes in their actions. Bodily et al. (2017) explored learner engagement in online environments by addressing issues related to pedagogical concerns, technological challenges, and interface design considerations. They indicated that dashboards can be used as a solution to interface design issues in the form of content recommender and skill recommender dashboards.

van Leeuwen et al. (2021) examined the effects of K-12 teachers' characteristics, such as gender, age, and self-efficacy, on their decision-making. Conducting two case studies, they concluded that these characteristics are not associated with teachers' use of dashboards. More recently, Borders (2023) investigated the affordances of data visualisation using dashboards in university students' learning. The results showed that having students create dashboards on the topic of study increased students' understanding of the subject matter and enhanced their data literacy and dashboard design skills.

Several studies have also been conducted in the realm of information systems. Tan et al. (2017) explored K-12 students' experiences with learning analytics dashboards and visualisation in Asian educational contexts. After a 16-week implementation of the dashboard design, students found the experience enhanced their self-awareness and self-regulated learning, increased their motivation and engagement, and fostered connective literacy between students. The downsides of dashboard design were found to be demoralising, pressurising, and inspiring complacency in students. Yoo and Jin (2020) developed and evaluated learning analytics dashboards to support online discussion activities. Having analysed online students' challenges during discussions, Yoo and Jin (2020) developed visual design guidelines to overcome the obstacles. Then, the guidelines were applied to create and evaluate the dashboards. The results indicated that students and instructors had positive attitudes towards dashboards, considering them novel, effective, simulating, and familiar. However, perceptions of dependability and attractiveness were below average.

Prokofieva (2021) developed a project-based activity for accounting students to emphasise various visualisation and dashboarding strategies in accounting and information systems. The effectiveness of the activity was then evaluated by administering three quizzes that assessed students' skill development. The results indicated that students found dashboards useful in enhancing their skills, and perceived them as a positive experience that will be applicable in their future careers. Finally, Chu (2022) examined the effectiveness of

designing dashboards to develop critical thinking in digital game-based environments. Designing dashboards after assessing students' critical thinking abilities confirmed that dashboards can be useful tools for reminding students of learning goals, explaining in-game behaviours, and giving personalised feedback.

As the synthesis of the literature shows, dashboards have been scrutinised from different perspectives and in various contexts. However, what warrants further investigation is their potential as an experiential learning tool in fostering learners' critical thinking abilities. Considering the original purpose of dashboards, they can be viewed as tools or interfaces that provide students with the opportunity to work with authentic data (concrete experience), reflect on their properties (reflective observation), devise solutions for problems (abstract conceptualisation), and present their solutions through dashboards (active experimentation) (Prokofieva, 2021). Going through these stages can foster students' critical thinking abilities, as hypothesised by Kolb (1984, 2014). Despite these potential benefits of dashboards, this aspect has received little attention in teaching analytical logic and critical thinking. Against this backdrop, the present study aims to answer the following research questions:

1. What are the effects of implementing student-created dashboards on students' critical thinking abilities?
2. What are students' and staff's perceptions about implementing student-created dashboards?

## 3. METHOD

### 3.1 Design

This study employed a design-based research approach, which is particularly suitable for studying complex educational interventions in real-world and technology-related learning settings (Barab & Squire, 2004; Wang & Hannafin, 2005). By combining empirical educational research with the design and refinement of learning environments (Design-Based Research Collective, 2003), this approach enabled us to develop, implement, and refine student-created dashboards in collaboration with instructors and students, ultimately fostering students' critical thinking abilities. Similar to mixed-method design, design-based research triangulates multiple sources of quantitative and qualitative data without being constrained by epistemological challenges associated with the nature of various data and research tools (Anderson & Shattuck, 2012). Moreover, the design-based research approach extends beyond theory-driven exploration and paves the way for the continuous refinement of practical interventions, thereby gradually enhancing the development and implementation of instructional treatments (as shown in Figure 1).

In this study, the quantitative data include students' scores on their final assessment, which involves creating dashboards to present their analyses and interpretations of a given dataset. Qualitative data comprise students' perceptions of implementing dashboards, collected via an open-ended questionnaire, and staff's perceptions gathered through semi-structured interviews. Adopting a design-based research approach enables us to build on students' learning outcomes and the perceptions of both students and staff regarding the intervention, resulting in a comprehensive dataset and sound conclusions about the effectiveness of our intervention (Design-Based Research Collective, 2003).

### 3.2 Context and Participants

Two first-year commerce subjects at an Australian university commencing in the first semester of 2018 were selected for this research. Both subjects explicitly listed critical thinking as a key learning outcome at the time. As part of their assessment, students had to create a dashboard and extract insights using them. Feedback from both students and staff indicated difficulties with the analytical aspects of creating and interpreting dashboards on both subjects because students did not possess sufficient critical thinking abilities to perform well on this assessment. Students' works often presented summaries or paraphrased material instead of the required in-depth analyses. Typically, students relied heavily on limited resources and did not gather enough information to perform effective analysis; therefore, they were often at a loss as to how to integrate, validate, and critique the resources at their disposal (Nentl & Zietlow, 2008).

Subject one, named Work Integrated Learning (WIL), is a first-year introduction to professional commercial skills that focus on industry research, analysis of changing employment requirements, forecasting future requirements, and development of employability skills. WIL had three assessment tasks: "my opportunities," "my profile," and "my application." Dashboards were embedded into the first assessment task. Students were required to create two dashboards and draw insights into their own capabilities and the industry in which they aspire to build a career.

Subject two, called Business Analytics and Statistics (BA), is a first-year introduction to business analytics and statistics. This subject provides students with the analytical knowledge and skills to explore data, identify patterns and relationships, evaluate decisions, and forecast and predict trends. This subject had four assessment tasks, including three summative assignments and an exam. In the assignments, students were asked to analyse a given dataset to answer specific questions based on a scenario. They then interpreted and drew conclusions from their analysis, conveying these conclusions in a written report to a person with little to no knowledge of business analytics. Furthermore, students were asked to develop an interactive dashboard to help a manager understand and visualize key business measures, allowing them to drill down into the data.

Each subject had over 2,000 students per year spread across multiple semesters. The students in both subjects came from diverse prior learning experiences, work-study configurations, and varied professional aspirations, and were also increasingly opting for online or hybrid modes of learning. Additionally, the removal or relaxation of enrolment caps led to an expansion in student numbers. Staff feedback was collected from the 20 teaching staff involved in the two subjects on their perceptions of the usefulness of the dashboards in teaching critical thinking, the impact on students, and any perceived changes in teaching.

### 3.3 Instruments

To collect both quantitative and qualitative data, this study triangulated multiple instruments. To answer the first research question regarding the effects of implementing student-created dashboards on students' critical thinking abilities, we gathered quantitative data on students' scores in the subjects before and after implementing dashboards. These scores served as an indicator of critical thinking ability because the course learning outcomes explicitly list critical thinking as a main component.

To address the second research question concerning students' and staff's perceptions about implementing student-created dashboards, we used an open-ended questionnaire and semi-structured interviews, respectively. Students' perceptions were collected using a Likert-scale item and two open-ended questions included in the end-of-subject survey. To obtain data on staff perceptions, we utilised semi-structured interviews that included four open-ended questions.

### 3.4 Procedure

The present study was conducted in four main phases (see Figure 1), collecting repeated cross-sectional data. More specifically, the data were collected at different time points (e.g., T1: 2020) from various participant groups (Rafferty et al., 2015). In the first phase, we collected data on student performance and staff comments. This phase utilised standard student feedback surveys to gather qualitative comments on students' perceived challenges. We also collected aggregated student performance data on the task designated to assess critical thinking. The data were collated after the completion of studies to prevent any influence on student performance. The analysis of the results from Phase One established the scope and parameters of the problem, informing Phase Two. In the second phase, the teaching staff from both subjects examined the literature and used the results from phase one to design or redevelop a new teaching and learning approach. In this approach, the teaching team relied on their teaching and assessment of real-world case studies throughout the semester and taught the students how to create dashboards. Taking a step-by-step approach and building on Kolb's experiential learning model, the instructors taught students what important aspects of data to focus on, reflect on their analyses, come up with solutions for the problems at hand, pick the most important aspects of data for data visualisation, choose the best data visualisation graph, and create reader-friendly dashboards. These steps corresponded with the learning cycle in Kolb's framework, i.e., experiencing, reflecting, thinking, and acting.

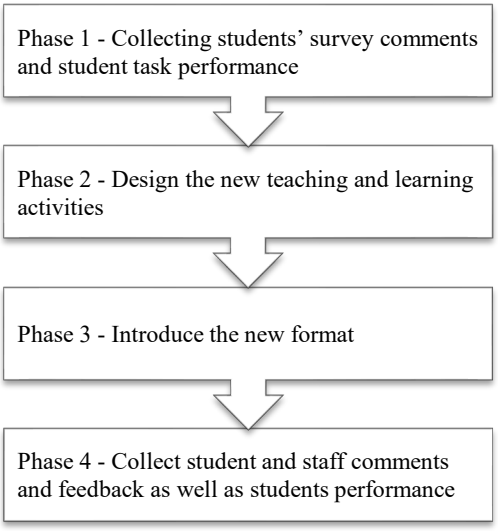


**Figure 1. The Phases of Conducting the Study**

Additionally, student-created dashboards were integrated as a part of the final assessment. Since the development and improvement of critical thinking and analysis were the main goals of this research, we aimed to solve the problems and create a replicable approach that could be used elsewhere and in other contexts. Phase Three introduced dashboards as a learning tool and a method for students to visualise their data in two first-year subjects. For the WIL subject, the dashboards were introduced in the second teaching period of 2018, and for the BA subject, the new design was introduced in the first teaching period of 2019. The assessment in both subjects required students to develop a dashboard to organise data, effectively display the data that contributed to comparative analysis and decision-making, and then produce insights. In the final phase, Phase Four, we reassessed student performance using aggregated and anonymised assessment data, anonymous student feedback from surveys, and student comments and questions posted to the subject discussion forums.

### 3.5 Data Analysis

To answer the first research question, student performance on the summative test was taken as an indicator of critical thinking abilities because the test assessed students' skills in critically analysing data, interpreting results, and presenting insights using dashboards. The percentages of participants' score ranges were reported before and after implementing the dashboards. To address the second research question about students' perceptions of the effectiveness of implementing dashboards, we analysed a Likert-scale item that measured students' satisfaction with the unit, as well as their responses to two open-ended questions on the end-of-subject survey. For the Likert-scale item, the percentage distribution of responses was reported. For the open-ended questions, comments were analysed through content analysis, and relevant excerpts were provided. Staff interviews were also analysed using content analysis, with pertinent excerpts reported to capture their insights.

## 4. RESULTS

To address the first research question, we used descriptive statistics to establish the baseline of students' results on assessments requiring critical thinking. As shown in Table 1, students' critical abilities improved after the implementation of dashboards. Students were better able to draw links between information from multiple sources, as reflected in a positive shift in grades across the cohort. After the introduction of dashboards to collate and present the research and analysis, the number of students achieving grades in the 60%-69% and 70%+ ranges increased. Table 1 provides a summary of the students' results on assessments that require critical thinking in the BA, and Table 2 presents the results for the WIL subjects. It is noteworthy that in 2022, the BA unit underwent a complete redevelopment, whereby creating interactive dashboards became a standalone assignment rather than being mixed with other analysis requirements. Moreover, each semester, the dashboard training was continuously improved (i.e., enhanced training) based on the feedback received from students and staff.

| Implementation Period | Grading Schema | | | |
|---|---|---|---|---|
| | Fail | Pass | Credit | (Higher) Distinction |
| T1:2020- Before intervention | 42% | 13% | 15% | 31% |
| T2: 2020- Pilot introduction | 29% | 14% | 16% | 41% |
| T1:2021- After intervention | 27% | 7% | 8% | 58% |
| T2:2021- After intervention | 24% | 11% | 9% | 57% |
| T1-2022- Enhanced training | 7% | 9% | 22% | 63% |
| T2-2022- Enhanced training | 2% | 8% | 23% | 66% |

*Notes:* Fail means scores below 50%, pass is 50-59%, credit is 60-69%, and distinction and higher distinction are 70-100%.

**Table 1. Students' Assessment Results in the BA Unit**

The second research question aimed to explore the students' and staff's perceptions of implementing dashboards. According to the satisfaction survey, students' perceptions indicated year-on-year improvement in students' satisfaction criteria, exceeding the set goals. Notably, in T1-2022, when responding to the item "Overall, I am satisfied with the unit," 90% of on-campus students responded "Agree" or "Strongly Agree," which is much higher than their initial satisfaction in T1-2018. Online students' satisfaction also improved drastically, from 57% to 89% over the three-year period. Furthermore, the satisfaction of online students with learning resources increased from 65% to 91% over the same time period.

| Implementation Period | Grading Schema | | | |
|---|---|---|---|---|
| | Fail | Pass | Credit | (Higher) Distinction |
| T1:2018- Before intervention | 15% | 25% | 28% | 38% |
| T2: 2018- Pilot introduction | 8% | 20% | 30% | 38% |
| T2 2019- After intervention | 9% | 19% | 34% | 39% |

*Notes:* Fail means scores below 50%, pass is 50-59%, credit is 60-69%, and distinction and higher distinction are 70-100%.

**Table 2. Students' Assessment Results in the WIL Unit**

The students' responses to the two open-ended questions in the satisfaction survey were also examined through content analysis to gauge their perception of implementing dashboards. The iterative content analysis process revealed both positive and negative themes regarding the use of dashboards. The positive themes suggested that students (1) were able to focus more closely on the research section of the assessment, and (2) perceived dashboards as relevant to their future careers and enjoyed using them. However, a negative aspect also emerged, which was associated with students' difficulties in understanding assessment requirements. Below, we discuss these themes along with illustrative student comments.

A significant positive aspect of implementing dashboards was that it led the students to conduct more extensive research and synthesise the information. Before the introduction of dashboards, students often skipped areas of research that were not easily accessible, which was reflected in their grades and feedback. After introducing dashboards, however, students had specific elements to complete, prompting them to research more broadly and synthesise and evaluate the information to "fill in the boxes." This process is a key component in the development of critical thinking skills, where students seek information, extend their personal views, question assumptions, and reflect on their actions (Dahl et al., 2018; Peltier et al., 2006). It also contrasts with the descriptive writing that previously characterised student submissions, where students accepted the authority of the sources without question (Erikson & Erikson, 2019).

> *"As someone that currently works in a middle management role, this unit has given me the confidence to take what I've learnt and use it in my decision-making and thought processes. For me it has given me a strong understanding of a lot of thought processes I already use and given me alternatives to be able to use to get stronger responses. The dashboard masterclass was a massive learning tool, definitely something that should continue for future units."*

Another major theme regarding the benefits of dashboards was their usefulness and relevance to students' future careers. Students also enjoyed creating dashboards. For instance, one student indicated that:

> *"The dashboard masterclass that he ran was amazing - I learned so much and feel as though I will be able to use the skills I developed in my future career."*

Regarding the downsides of implementing dashboards, a recurrent theme suggested that it was difficult for students to understand what was required of them. In the words of another student:

> *"I felt the dashboard section needed further instruction in the assignment brief about what is expected ... I still don't fully understand where I went wrong with the dashboard."*

The interviews with the 20-teaching staff involved in the two subjects were transcribed and analysed through content analysis. The interviews aimed to explore the staff's perceptions about the usefulness of the dashboards in fostering critical thinking and any perceived changes in teaching. Some of the most frequent themes emerging from the interview data are summarised in Table 3.

When asked about the key features of dashboards in their classes, 42% of respondents identified that it was the ability to summarise, consolidate, and visually represent data; 20% said it allowed students to find patterns in data, and about 19% said it aids data analysis. For example, one teacher indicated that:

> *"The dashboards have actually made it easier to explain how the information links together and to highlight what students may need to be aware of (which I did previously but it is easier with dashboards). In addition, being able to refer students back to the information in their dashboards (rather than specific pieces of information) throughout the semester and for each assessment has been easier."*

| Question | Most common response | Common responses | Some responses | Few responses | Least common response |
|---|---|---|---|---|---|
| What do you think are the key features of dashboards in an education environment? | Summarise data | Makes decision making/analysis/interpretation easier | Useful for future studies/employment prospects | Allows student to reflect on themselves/ their learning | Speeds up communication /interactivity |
| Do you believe the introduction of dashboards in assessments has had an impact on student performances? | Yes | – | No/ Not Sure | – | Some Students |
| Do you think dashboards have led to an improvement in students' ability to integrate information from multiple sources? | Yes | – | Some Students | – | No |

**Table 3. Teachers' Perceptions About the Usefulness of the Dashboards**

Regarding the effects of dashboards on students' performance, 69% of teachers felt that the introduction of dashboards positively affected students' performance, while 19% felt that it did not, and 12% were unsure of its effects. Additionally, 81% agreed that dashboards have led to an improvement in students' ability to integrate information from multiple sources. Furthermore, the respondents indicated that it allowed students to cover research requirements in more depth (37%), enabled a holistic view and better organisation of ideas (37%), and allowed them to be creative (5%). Another teacher, for instance, said:

> *"The dashboard gives the students a format to structure their research and findings and therefore guides their research as they are filling in the various sections."*

When asked specifically about students' critical thinking abilities and their ability to manage data from multiple sources, 88% of the teachers felt that there had been either "some" or a "significant" improvement in these skills. In a similar vein, 59% of the teachers felt there had been "some" or a "significant" improvement in students' problem-solving skills, mainly due to students' better understanding of research requirements (45%). In the words of one teacher:

> *"There is a need to complete the dashboard and create the 'complete' visual poster. Previously when they wrote this information up as text there were often sections missing. There is almost a human-driven need to complete the whole thing as it is visual and missing information is obvious."*

The results obtained from different sources show that implementing dashboards not only improved learners' satisfaction and performance in the unit but also received favourable views from both students and staff. In the following section, the findings will be discussed.

## 5. DISCUSSION AND CONCLUSIONS

The present study built on Kolb's (1984) experiential learning theory to examine the effects of implementing student-built dashboards on students' critical thinking skills. It also aimed to explore students' and staff's perceptions about using dashboards. Students' performance on the final assessment, which primarily targeted their critical thinking abilities, indicated a significant increase in learning outcomes compared to the previous semesters. The results of the satisfaction survey suggested that learners were highly satisfied with the subject and benefited from dashboards in several ways.

Moreover, interviews with staff revealed that they also favoured using dashboards, noting an increase in students' critical thinking and higher-order thinking abilities.

This research examined the affordances of student-built dashboards on learners' critical thinking abilities in large cohorts. The gradual increase in the mean score on the final assessment of the unit can be seen as a clear indication of the effectiveness of implementing student-built dashboards. More specifically, it can be argued that introducing dashboards as a tool that would engage learners in experiential learning processes has equipped learners with critical thinking, or more specifically, the ability to integrate all the information effectively, explore it more closely, and justify it more convincingly (Kachouie et al., 2024; Kurfiss, 1988). Applying these abilities to their final assessment of the unit, which also targeted critical thinking skills, has therefore enabled learners to achieve higher scores compared to previous periods when student-built dashboards were not introduced into the units. Seen in this light, it can be argued that student-built dashboards can function as an effective tool to enhance learners' critical thinking abilities, which can be applied to different domains. Two points are noteworthy: 1) successful performance on final assessments hinged on students' having critical thinking abilities, so higher scores would mean higher critical thinking abilities based on our conceptualisation; and 2) the only difference between pre- and post-intervention periods was implementing dashboarding. That is to say, all aspects of the units were the same, except for the introduction of dashboarding throughout the semester. Thus, it might be safe to attribute the findings to the implementation of student-built dashboards.

Regarding the findings on students' increased satisfaction, it can be concluded that learners were satisfied with building dashboards. Although detailed tools to delve into students' perceptions of student-built dashboards regarding different aspects of critical thinking abilities, especially at each level of Bloom and Krathwohl's (2020) scale, were not available, the current findings indicate that implementing student-built dashboards has augmented their satisfaction. This could

indicate that initiatives such as implementing student-built dashboards can engage learners in activities that they perceive as useful for their future careers, making them more willing to invest in and participate in them. This, in turn, can enhance their overall satisfaction with the entire unit. This effect was more pronounced for online students, which could point to several possibilities, such as increasing their engagement with course materials and/or allowing them to practice with hands-on tasks that mimic real-world activities.

One might argue that these contentions may be far-fetched, as data were not collected using fine-grained tools that target the role of student-built dashboards. However, the only difference between the unit offered in this period and that offered previously is the introduction of student-built dashboards. In other words, only the implementation of student-built dashboards was new in the unit, so it can be argued that the change in students' satisfaction levels can be attributed to the introduction of this initiative. Nonetheless, finer-grained tools are required to confirm this conclusion. Finally, the findings indicated that the teaching staff were also in favour of implementing student-built dashboards. As their interview data clearly showed, the teaching staff were satisfied with the fact that student-built dashboards enabled the students to draw links between different pieces of information, collate them more effectively and critically, and present their findings. Based on this premise, it can be observed that the teaching staff are highly likely to have positive attitudes about the implementation of student-built dashboards as tools that would enhance learners' critical thinking abilities.

From a theoretical vantage point, the findings lend credence to Kolb's (1984, 2014) experiential learning framework. Based on the findings of the present study, it can be inferred that experiential learning with the appropriate tool (i.e., dashboards) can enable learners to move from lower levels of thinking to higher levels of synthesising and critically analysing different concepts. Specifically, it can be argued that dashboards enabled the students to successfully go through the concrete experience, reflective observation, abstract conceptualisation, and active experimentation stages to reach higher critical thinking abilities. The findings are also consistent with previous empirical studies. More specifically, the findings resonate with those of Mustafa et al. (2022), who reported that experiential learning fosters students' critical thinking abilities. Similarly, it is in line with Voukelatou's (2019) study, as he reported that students' critical thinking was enhanced as a result of implementing project-based teaching, an experiential learning approach. Focusing on the use of dashboards, more specifically, the findings are consistent with those of Borders (2023). In line with his findings, the present study demonstrated that learners were able to delve more deeply into the topic, conduct further research on its various aspects, and ultimately gain a more nuanced understanding. This reflects a transition towards critical thinking, which aligns with Borders' (2023) findings.

The finding that building dashboards increased students' critical thinking abilities aligns with Chu's (2022) research, which suggests that dashboards can be effective in equipping learners with critical thinking skills. Furthermore, students' and instructors' satisfaction with implementing student-built dashboards is consistent with the findings of Tan et al. (2017), Yoo and Jin (2020), and Prokofieva (2021). Similar to these studies, our findings indicated that students perceived dashboards as relevant to their future careers and enjoyed using them. Similarly, the instructors were satisfied with implementing student-built dashboards, since they could improve students' performance. In summary, the outcomes from implementing dashboards in both units revealed an improvement in overall student results, an increase in students' ability to draw insights, and an enhancement in students' critical thinking skills.

The findings of the present study can bear theoretical and pedagogical significance. Regarding the former, the findings of the present study expand the scope of Kolb's (1984, 2014) experiential learning theory by confirming that it can pave the way for students to reach higher levels of critical thinking. Thus, it unravels the potential of implementing dashboards as a useful tool in supporting students' learning, developing their critical thinking skills, and increasing their employability. The pedagogical significance of the findings is for curriculum designers, material developers, and teachers. Curriculum designers can be encouraged to incorporate dashboard design in teaching and assessment. For instance, information system educators can create industry-aligned dashboard projects that enable students to solve authentic challenges in the industry. This can further scaffold students' learning and critical thinking by integrating Bloom's taxonomy, guiding them from analysis of datasets to evaluation, followed by dashboard creation (Prokofieva, 2021). Moreover, educators can create feedback loops throughout the dashboard creation process, critique students' analyses and evaluations, and foster their critical thinking in an iterative approach (Chu, 2022). This can prove useful in learners' employability by adding to their repertoire of skills, such as dashboard design and critical thinking.

The findings can also have cross-disciplinary applicability within information systems education. Hands-on dashboard creation might be able to foster critical thinking in disciplines such as cybersecurity by allowing students to analyse attack trends, prioritise risks, and justify mitigation strategies. Similarly, dashboards can simulate data-driven decision-making processes in the workplace to foster students' critical thinking abilities in balancing data-driven insights with ethical considerations (e.g., in health informatics), identifying bottlenecks in resource allocation (e.g., in software engineering), and balancing quantitative data (e.g., human-computer interaction). Therefore, educators in information systems can incorporate the dashboard design in their units for teaching and assessment purposes.

## 6. Limitations and Directions for Further Research

Caution should be exercised in generalising the findings because there were some limitations in the present study. First, the development of students' critical thinking was operationally defined as their performance on the final assessment. Although the final assessment taps into major aspects of critical thinking, the inclusion of a separate tool to measure critical thinking would be more illuminating. As one of the reviewers aptly pointed out, new data collection tools can be developed corresponding to the specific definition or role of critical thinking abilities, and the data can be analyzed using statistical analyses, which would shed more light on the issue being studied. It is also worth researching whether and how using dashboards can impact critical thinking abilities at each level of Bloom and Krathwohl's (2020) taxonomy. Second, the present study examined whether having students build dashboards

would enhance their critical thinking abilities. As critical thinking is defined concerning a specific subject or domain (McPeck, 2016), the findings can only be indicative of students' enhanced critical thinking abilities in collating, analysing, reporting, and visualising statistical procedures and data using dashboards. Whether students actually apply such critical thinking abilities in real work in the future remains to be investigated. Similarly, another avenue for further research could be examining industry perspectives on whether and how implementing student-created dashboards affects students' chances of employment and benefits their performance.

Third, students' enhanced performance on the final assessment might have been confounded by other variables, not just the implementation of student-built dashboards. For example, students' baseline analysis abilities and prior exposure to data tools were not controlled for, so they might have unduly affected their dashboard creation experience. Additionally, students' interest in and engagement with dashboard design or career aspirations might have mediated the effects of dashboard design on their critical thinking and perceptions. Therefore, there is an avenue for further research on the effects of implementing student-built dashboards on the development of students' critical thinking abilities, using more robust experimental designs that take confounding variables into account. For instance, data about students' performance and perceptions before administering the intervention can be collected and compared with the post-intervention data using inferential statistics. Control groups can also be included to ascertain the role of the intervention more confidently, and to control for the effects of other variables, such as students' background knowledge and motivation (Tan et al., 2017), thereby providing more rigorous insights into the effects of dashboarding. Finally, student-built dashboards were implemented in only two subjects of the Business Analytics program. Future studies can examine whether implementing student-built dashboards with more subjects across different disciplines affects students' critical thinking abilities and satisfaction differently.

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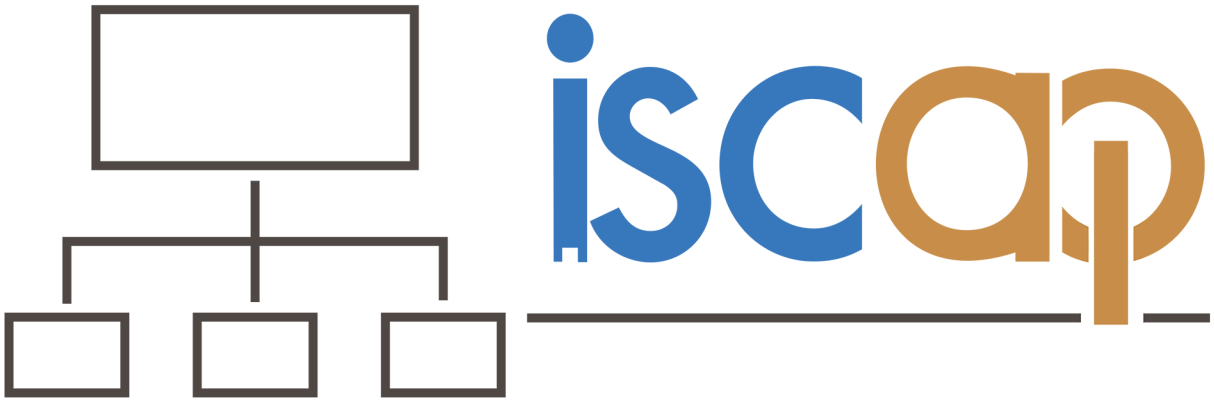


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