Promoting Evidence-Based Decision Making Practices to Develop the Entrepreneurial Mindset Enabled by Microsoft Power BI Desktop

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***Abstract*—The entrepreneurial mindset is defined as the inclination to discover, evaluate, and exploit opportunities. One approach to developing the entrepreneurial mindset is through evidence-based decision-making, which has the potential to lower costs, improve quality of life, and even save lives by understanding learning patterns and trends related to data, in general, and big data, specifically. As a result, data science solutions are being increasingly deployed in the business world, and the growth of publicly accessible data provides a significant opportunity to transform educational efforts related to data science. This is of particular importance to the engineering and computer science fields given the increasing focus on big data and evidence-based decicision making. As such, the purpose of this study is to report on one approach to developing the entrepreneurial mindset through integrating evidence-based decision making into the engineering and technology classroom using Microsoft Power BI Desktop, a freely available tool released by Microsoft in September 2013. The study was assessed using a mixed methods approach, including a rubric to measure demonstration of the entrepreneurial mindset and metacognitive reflection to better understand student awareness of learning. The findings were categorized into two key themes related to each high performing and low performing groups. The high performers (1) expressed more concerns related to the "big picture" and "critical thinking" based challenges primarily focused on the research and solution, and (2) articulated coping habits and methods used to overcome stress. The low performers (1) highlighted challenges related to time management and procrastination and (2) confusion about project requirements and how to do the required tasks (which is believed to be attributed to missing classes). Lessons learned and recommendations are provided.**

Keywords—undergraduate, decision making, software, big data, metacognition, cognitive apprenticeship, entrepreneurial mindset

I. Introduction

A. Problem Identification

How can higher education prepare students for their professional lives when professions themselves are disappearing? ~ Joseph Aoun

Joseph Aoun responds to this question in the book, Robot-Proof: Higher Education in the Age of Artificial Intelligence by justifying the need to develop new literacies, including technological literacy, data literacy, and human literacy [1]. One approach to simultaneously developing all three literacies is through teaching students how to get insights from data enabled by Microsoft's Power BI Desktop. Technological literacy can be facilitated through using the Power BI Desktop application (e.g., technology) as a mechanism to access, evaluate, and communicate information. Data literacy can be acquired through a number of Power BI's features, including data organization, data visualization, and data interpretation. Human literacy, although not directly embedded within the Power BI Desktop application, can be incorporated using datasets grounded in economic justice, social entrepreneurship, and pop culture, all of which resonate well with younger, diverse audiences. Unfortunately, a limited curriculum exists to support faculty (and students) in this endeavor, which is a barrier to knowledge acquisition and technology adoption.

B. Purpose of this Study and Research Questions

The proposed solution to the aforementioned problem, is to develop a new approach to teaching and learning an entrepreneurial mindset enabled by Microsoft Power BI Desktop. The purpose of this study is to provide preliminary results of implementing the new curriculum and assessment for this project. A key feature of this project is that the design of the learning materials will be grounded in a constructivist learning theory using the cognitive apprenticeship approach [2]. Thus, the intervention applies both entrepreneurial-minded learning and computational cognitive apprenticeship; and the assessment is a metacognitive reflection. The guiding research question is as follows: *How can metacognitive reflections be used to better understand student perceptions when working on an entrepreneurially minded curriculum grounded in computational cognitive apprenticeship pedagogies?*

II. Background

A. Decision Science Focused Learning

By definition, decision science is a collection of quantitative methods that can be used to drive decision making, which considers decisions such as risk assessments, cost-effectiveness, simulation modelling, and cost optimization [3]. Concepts from statistical inference, micro and macroeconomics, computer science, and behavioural psychology are used to value potential judgements underlying opportunity costs and decision making tradeoffs.

Instruction within decision science focused learning is often scaffolded where students are presented with real-world scenarios or simulations while being guided through relevant

decisions until an 'endpoint' where a final action is taken. To prevent over-reliance on a specific algorithm of decision making, students are presented with vaguely defined scenarios that require them to adapt and restructure internalised knowledge to create new decision models from the ground up [4].

Decision science focused learning often includes basic and applied research to build program models, model evaluation to test effectiveness, and practitioner knowledge to improve models [5]. These components are linked by the singular feedback process, which makes this a cyclical improvement process rather than a static education model. However, research and evaluation inherently only work well when clear objectives and goals are defined. The lack of these goals and expected outcomes may question the validity of the model itself. Moreover, evidence-based methods and designs must be tested over a large sample to ensure its reliability across various curriculums and age-groups.

Incorporating large amounts of data into every practices allows one to go beyond opinion and gut feel, moving more towards evidence-based decision making [6]. The application of evidence based methods ensures that adopters use the best existing evidence as a foundation while allowing the flexibility for improved measures. That being said, student centered, instructional based models in the form of simulations [7] have been proven to be an effective teaching-learning strategy in undergraduate curriculum by means of providing clinical expertise in a safe environment to nursing students.

B. Current Approaches to Teaching Power BI

Currently, there are two main approaches to introducing Power BI to novice audiences. First, the Microsoft Power BI website offers some "tutorials," however, usability in the classroom is limited for a few reasons. Many of these "tutorials" aim to passively demonstrate how features work yet fail to provide the data to promote active learning opportunities. Second, for the few tutorials that do include data, the context is too advanced for a general class (e.g., Build a machine learning model, the dataset does not promote relatability to a diverse audience (e.g., Import and analyze webpage data + Football Championship Data), and the directions require the use of the Power BI Cloud Service which isn't available to students (e.g., Use Cognitive Services).

A second approach to the problem is to purchase a workbook for students to follow along. Although many books are available that showcase how to use Microsoft Power BI (including the use of the cloud service), limited books focus on the Power BI Desktop application itself. And even fewer books (only one came close, to the best of our knowledge) is a tutorial that includes data to gain hands-on experience. This book is available through Amazon and is titled the Microsoft Power BI Desktop - Creating Visual Reports by Jeff Hutchinson. This book has been used by the first author for two semesters, and many problems have been identified (which may explain the low Amazon review score). First, errors exist. Second, the tutorial incorporates the cloud service (which isn't available to students). Third, the book has nine chapters; only the first two chapters are project-based (where students analyze data to create a report); the remaining seven chapters are features based (with limited hands-on interaction). Furthermore, although portions of these materials may be technically and computationally sound, they are not grounded in learning theory or evidence-based approaches to teaching and learning.

III. Theoretical Foundation

A. Computational Cognitive Apprenticeship

The content of the curriculum is delivered via a computational cognitive apprenticeship [8]. Computational cognitive apprenticeship is an adaptation of cognitive apprenticeships for enabling the development of computational and data science practices. Cognitive apprenticeship [2] is an instructional approach that emerges from comparisons between traditional classroom instruction and the cultural tradition of apprenticeship, which more prominently features observation, coaching, and successive approximation [9]. Cognitive apprenticeship (CA) proposes six specific methods to help students acquire integrated knowledge and skills: (1) modeling, where the instructor demonstrates how to perform a task; (2) coaching, including observation and facilitation at the moment students perform a task; (3) scaffolding, regarding supporting methods to help students perform a task; (4) articulation, consisting of instructors encouraging students to state their knowledge and thinking; (5) reflection, where instructors enable students to compare their performance with experts; and (6) exploration, prompting students to solve problems on their own [2].

B. Entrepreneurial Mindset

The entrepreneurial mindset is defined as "the inclination to discover, evaluate, and exploit opportunities" [10]. Additionally, the Kern Family Foundation [11] describes the entrepreneurial mindset as to how individuals think about the world and act upon what they see. It is a culmination of mental habits that empower people to question, adapt, and drive change in their communities, societies, and ultimately, the world around them. To cultivate the entrepreneurial mindset, Bosman, et al. [13] proposed four intentions that educators should be cognizant of while integrating the entrepreneurial mindset into the existing curriculum. The four intentions [13] are as follows:

- Intention 1: The learning activity should provide an experience to discover, evaluate, and/or exploit opportunities. Opportunities that create the most value should be aimed at customer desirability, technology feasibility, and business viability.
- Intention 2: The learning activity should provide an experience to develop professional skills (collaboration and communication)
- Intention 3: The learning activity should provide an experience for continued practice, reflection, and feedback.
- Intention 4: The learning activity should be aligned with and reinforce learning goals, learning objectives, and learning assessment.

C. Metacognition

According to Flavell [14], metacognition describes the process of formulating strategies positioned to choose from a set

of available cognitive mechanisms, given what the individual understands about their own motivations, assumptions, strengths, and weaknesses. For example, to think metacognitively means to describe such activities as "to reflect, to think aloud, to plan, to be strategic, to be self-aware, to self-monitor, to have a plan" [15]. Furthermore, Rhodes [16] refers to metacognition as a set of processes that an individual uses in monitoring ongoing cognition so as to have control over one's own behavior. Literature suggests that effective teaching of metacognitive skills improves student learning. This indicates that students who are taught metacognitive skills tend to learn better and make better progress than students who are not taught such skills [17]. Metacognition includes knowledge of strategy, task, and person variables [14]. In line with this framework, Pintrich [18] further divided metacognitive knowledge into three categories: 1) strategic knowledge (student knowledge of general strategies for learning and thinking, 2) knowledge about cognitive tasks (student knowledge of cognitive tasks including how and when to use strategies), and 3) self-knowledge (student performance in relation to cognitive and motivational components). Metacognitive knowledge plays a significant role in student learning and, by extension, how students are taught and assessed in the classroom [19].

IV. Methods

A. Study Design

Student participants completed a 5-week entrepreneurially minded module using evidence-based decision making. Weeks 1-4 followed the cognitive apprenticeship approach using a variety of pedagogical approaches, including in-class group assignments, online discussions, and completion of a Power BI lab. Week 5 required students to complete a project (graded via a rubric), followed by a metacognitive reflection. Section 3.2 describes the participants. Section 3.3 summarizes the entrepreneurial-minded intervention, which integrates the cognitive apprenticeship approach and metacognitive reflection. Section 3.4 highlights the data collection and assessment approaches.

B. Participants

Participants include senior-level students enrolled in a technology course titled, "Leadership Strategies for Quality and Productivity." Per institutional data, the class size was 34 students including 19 males and 15 females. The course catalog description is as follows: "This course is a study of how organizational leaders create an environment conducive to high levels of employee self-motivation, quality, and productivity. Emphasis is placed on process and systems thinking. Actual case situations, experiences, and applications from current events are used to illustrate the application of course content. The intent is to provide students with profound knowledge, understanding and leadership practices which are essential for establishing and continually improving organizational effectiveness through the prevention and solution of workplace problems." This study was approved as IRB exempt category #1.

C. Intervention

1) Entrepreneurially Minded Module

The entrepreneurial mindset is defined as "the inclination to discover, evaluate, and exploit opportunities [20, 21]". As such, each of the four weeks focused on exploring a different aspect of the entrepreneurial mindset, as shown in Table 1.

Table 1. Entrepreneurially Minded Module - Explained

Week	Description of Entrepreneurially Minded Integration
1	Discovery: Problem Identification (Students Identify Topic Area)
2	Discovery: Problem Justification (Using Power BI)
3	Evaluation: Current Approaches & Gaps in Current Approaches
4	Exploitation: Proposed Solution
5	Culminating Project (Table 2): Discovery + Evaluation + Exploitation

Table 2. Culminating Project - Details

Student Directions: Keep headings and formatting. Sections 1-4 should be a minimum of 1000 words and include 3-5 citations.
I. Problem Identification and Justification <Insert problem identification and justification: (1) Select a data set of your choosing (only one student per data set) based on the approved data list to justify a problem. (2) Include a sentence that summarizes the problem (e.g., "The problem is…"). (3) The justification should reference a minimum of three Microsoft Power BI visualizations located within the Appendix. Each visualization should include a claim, evidence (e.g., reference the visualization within the Appendix), and reasoning. (3) Identify a research question.>
II. Current Approaches to the Problem <Insert current approaches to the problem: This section should identify a minimum of 3 current approaches to the problem.>
III. Gaps in Current Approaches <Insert gaps in current approaches: For each current approach mentioned in Section 2, this section should provide a gap (i.e., reason why the approach doesn't completely solve the problem identified in Section 1).>
IV. Proposed Solution <Insert proposed solution: This section should propose a new solution in response to the problem identified in Section 1, which is different from the current approaches mentioned in Section 2, and overcomes the gaps stated in Section 3.>
V. Appendix: <Insert a minimum of 3 Microsoft Power BI visualizations. Provide a caption for each visualization and reference the caption/visualization within the Introduction section.>

2) Cognitive Apprenticeship Approach

The five-week module followed the six steps of the cognitive apprenticeship approach, as shown in Table 3. Each week students learned a new focus area

Table 3. Cognitive Apprenticeship Approach Applied to Entrepreneurially Minded Module

Cognitive Apprenticeship Steps	Intervention Description
Modeling	During the lectures (in-class group work + Power BI labs), the instructor introduces students to the topic areas and provides an overview of how to perform the task.
Coaching	Students obtain immediate instructor feedback during the lectures.
Scaffolding	Students get to practice the task 3 times: (1) lectures, (2) online discussion, and (3) final project.
Articulation	Students shared learning via an online discussion, which allowed for articulating and demonstrating knowledge gains.
Reflection	Students were required to provide feedback on at least two peer posts, which allowed for comparing their performance with their peers.
Exploration	Students were prompted to select their own dataset for the culminating project.

3) Metacognitive Reflection

Metacognition is an awareness of analysis of one's own learning or thinking process. Upon submission of the project, students completed a metacognitive reflection including these questions:

- What was the most challenging part of this project?
- How did you overcome the challenge?
- Now that this project is complete, what positive learning habits/experiences will you carry forward to the next project?
- What negative learning habits/experiences will you do differently?

D. Data Collection and Analysis

The two core data collection instruments. First is the final project (3.3.1). The final project was assessed via a 10-item rubric including the following focus areas: (1) claim, evidence, reasoning, (2) problem articulation, (3) current approaches, (4) alignment of current approaches to the problem identified, (5) gaps in current approaches, (6) alignment of the solution to the problem identified, (7) solution articulation, (8) solution overcomes gaps, (9) formatting – citations, and (1) formatting – word count. The project provides a demonstration of the participants' ability to apply entrepreneurial thinking.

Second, is the metacognitive reflection (3.3.2). The metacognitive reflection used thematic analysis, which is defined as a foundational qualitative method for discovering patterns within the data [22], to identify themes. First, the researchers familiarized themselves with the data by reading and rereading student responses to the metacognitive reflection questions. Second, the NVivo Pro 12 qualitative analysis software was used to code the reflections. Third, after coding, the researchers searched for patterns within the data. Fourth, the researchers examined the data to generate and agree upon initial themes. Fifth, direct quotes were drawn from the reflections to allow readers to make their own judgments on credibility, accuracy, and fairness [23]. Lastly, the authors revised the themes (as needed) and wrote up the results section.

As a result of the rubric-based analysis, students were grouped according to performance. Then, the different groups were assessed separately to identify themes within the metacognitive reflection.

V. Results and Discussion

A. Grouping According to Project Score

The descriptive statistics of the performance data are provided in Table 4, and the frequency of scores is provided in Figure 1. The average project score for the thirty-four projects was 86.8, with a standard deviation of 12.6. In addition, 17 students earned a high score within the range of 90-100; 8 students earned a medium-range score between 80-89; on the low end, 9 students earned a score of less than or equal to 79. For the purpose of analyzing the metacognitive reflections (and due to limited space), it was decided to compare the high achieving group (90-100) to the lowest performing group (<=79).

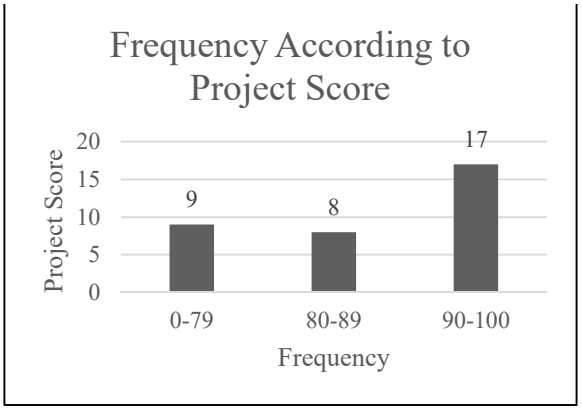

Figure 1. Frequency According to Project Score

Table 4. Descriptive Statistics for Project Score

Performance Level	N	Avg	Std Dev	Avg Assignments Completed
High (90-100)	17	95.9	3.5	80.1%
Medium (80-89)	8	86.4	2.1	73.5%
Low (<=79)	9	69.9	11.3	64.9%

B. Metacognitive Reflection Thematic Analysis by Group

1) High Performing Group

Preliminary thematic analysis was completed for the high performing group (90-100 score range), which included 17 students. The high performer group expressed more concerns related to the "big picture" and "critical thinking" based challenges primarily focused on the research and solution. Example quotes are provided here:

- "The most challenging part of this project was **finding reliable sources** that could answer my question that also contained enough information to come up with a thorough evaluation of the data given."
- "**Finding new solutions** that aren't already proposed and either for a common person or corporation was difficult."
- **"**The most challenging part of this project was the outside research I needed to do. Politics and diplomatic relations are not a specialty of mine, so **I had to be creative with the knowledge** I had and had obtained."
- **"**The most challenging part of this project was most definitely **trying to find a new solution** for the covid-19 virus that hasn't even been completely solved in real life, even with all of the world's experts working on finding solutions for the last 2 years."
- "The research took a while since I wanted to **find quality sources** that were authoritative on the subject.

A secondary theme was related to coping habits and overcoming stress. This group of students not only shared frustrations but how they overcame the frustrations. Example quotes are provided here:

- "I had believed that this project was going to be taxing and boring before I even investigated it. The tactic I plan to use in the next project is **keeping an open mind to the new information** I was handed."
- "At first, it was a bit stressful and time-consuming working with my first data set. However, I knew the rest of the **project would be easier if I chose a data set that was more comprehendible**, so I took the time and found a new one."
- "Next time, I plan on creating a rough draft or at least begin some initial research ahead of time. This will allow me to **not feel overwhelmed** at all once, and work at a smaller, slower pace."
- "I have many strategies that I have developed through my academic career and previous work experience that I can use **if I get stressed or if something seems hard**. These strategies really help, and I even used a bunch of them for this project."
- "I guess one negative habit I have that I will work on for the future is **not getting frustrated** when something doesn't work right away. Even when this does happen, I can just go for a walk outside and come back refreshed and can usually get it done."

2) Low Performing Group

Preliminary thematic analysis was completed for the low performing group (<=79 score range) which included 9 students. The biggest challenge for the low performing group was related to time management and procrastination. Example quotes are provided here:

- "I think that one thing that I could do, though, is **prepare a little bit better**. There is a difference between starting early and preparing. If I prepared a little better then maybe I would have had a topic that actually worked well on Power BI in the first place."
- "Next time, I will work ahead on Project 3 so that I am **taking my time** when completing the project."
- "I think negative learning habits that I will do different is making sure that I **do not procrastinate** and making sure that I get a head start in the work that I do. I had spring break and knew that I had this project coming up and waited until I got back from spring break to start."
- "Once I started to struggle with generating the visualizations, then I realized that I **underestimated the [time to complete the] project**."
- "Procrastination is one of my biggest downfalls in almost every part of my life. I would have **procrastinated whether this was a small assignment or a big paper**, and it is something I desire to change about myself."

A secondary challenge was related to the students being confused about the project requirements. Example quotes are provided here:

- "I was **generally confused on how to construct the report** and looking at the report in the example that was given to us did not make a lot of sense to me."
- "If I was able to find a data set that I was able to download, some of them would **download in very weird formats that would not even be able to work on Power BI**."
- "I would say it was making the visualizations on BI. I would **struggle for hours** trying to figure out how to transform my data the right way but hopefully I got it right in the end."
- "Microsoft Power BI has **caused me many challenges**. At the beginning of the year, I struggled to get this software onto my MacBook, so I have just had various problems with this."
- "I can do more research and work with the software that I have to use beforehand, instead of **going in shaky like I did**."

C. Summary and Lessons Learned

In summary, as a result of the rubric-based analysis, students were grouped according to performance level (which demonstrates entrepreneurial thinking). Then, the different groups were assessed separately (using thematic analysis of metacognitive reflections) to identify themes and areas for improving the curriculum.

The guiding research question was as follows: How can metacognitive reflections be used to better understand student perceptions when working on an entrepreneurially minded curriculum grounded in computational cognitive apprenticeship pedagogies?

The preliminary findings show two main themes for the highest performing group. First, this group expressed more concerns related to the "big picture" and "critical thinking" based challenges primarily focused on the research and solution. As a lesson learned, the instructor will update the module to

include a handout summarizing best practices for conducting research and identifying sources. Although these are senior-level students who have previously completed a course on technical writing, students can often benefit from a reminder of what transferable skills can be used and how it can be used. Second, this high performing group was very articulate about coping habits and methods used to overcome stress. As a lesson learned, the instructor will update the course curriculum to include a "student success" strategies on the first day of class. A handout will be provided, which includes approaches used by previous students for the new incoming students to consider.

In addition, the preliminary findings show two main themes for the lowest performing group. First, the primary challenge of this group was related to time management and procrastination. Similar to coping methods, these concepts fall under the umbrella of "student success" strategies; thus, this topic will also be discussed on the first day of class. Second, this low performing group stated challenges related to confusion about project requirements and how to do the required tasks. This theme was initially confusing for the instructor, as deploying the cognitive apprenticeship approach allowed opportunities for students to practice multiple times and get immediate feedback. Thus, additional analysis was completed to better understand the reason for the confusion – Poor teaching approach? Or missing class? For each of the four weeks leading up to the culminating project, students were required to attend lectures twice a week (in-class group assignments + Power BI lab) and post to an online discussion. This resulted in a total of 12 assignments (4 weeks x 3 assignments). Per Table 4, the high, medium, and low performing groups respectively completed assignments with an average of 80.1%, 73.5%, and 64.9%. From a correlation perspective, this implies that class attendance played a substantial role in project performance. This provides preliminary support that one aspect of the intervention (cognitive apprenticeship approach) does indeed work when students actually attend class and complete the assignments.

VI. Conclusion

In conclusion, data science solutions are being increasingly deployed in the business world, and the growth of publicly accessible data provides a significant opportunity to transform educational efforts related to data science. One approach to developing evidence-based decision-making is through entrepreneurially minded learning, which has the potential to lower costs, improve quality of life, and even save lives by understanding learning patterns and trends related to data, in general, and big data, specifically. When coupled with the computational cognitive apprenticeship approach, students will receive the guidance, scaffolding, and feedback necessary to improve performance and learning outcomes. As we look to develop more T-shaped engineers, where students have both a depth of knowledge (e.g., Microsoft Power BI and evidence-based decision making) and breadth of knowledge (e.g., a variety of real-world contexts), exploring further opportunities to teach evidence-based decision making is extremely important. Future research should (1) consider more sophisticated quantitative analysis, (2) increase sample sizes, and (3) disseminate best teaching practices related to integrating decision science-focused active learning (in comparison to traditional passive learning) into the STEM classroom.

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