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# Implementing Decision-based Learning in a Peruvian University

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A thesis submitted to the faculty of
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Master of Science

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# ABSTRACT

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Decision-based learning (DBL; Plummer, Swan, & Lush, 2017) addresses the difficulty that professors may have when teaching their expertise to their students. The purpose of this study was to understand the perspectives of professors and students implementing DBL in a Peruvian university. Professors at a Peruvian university implemented the DBL pedagogy in their classes. The research questions were (a) how effectively can professors in a Peruvian university implement DBL, (b) what benefits and challenges do professors perceive from implementing DBL, and (c) how did using DBL as a homework strategy affect student learning? We collected 74 implementation videos, 42 professor surveys, 5 professor interviews, 34 student surveys, 2 student interviews, and we performed an independent samples *t* test to explore if DBL influenced student academic achievement. Professors implemented the pedagogy at a 72% fidelity level. Professor benefited from the pedagogy for its practicality and struggled with the amount of preparation required. Students benefited from the ability to correct their mistakes and struggled with needing to put more effort into their DBL homework. The *p* value of the independent samples *t* test was 0.002. The students who used DBL outperformed the students who didn't use DBL on the quiz. In conclusion, DBL seems beneficial but some aspects of the pedagogy should be adjusted to make it easier for professors to prepare and students to experience. Future research should include how DBL affects professors and students when implemented for longer periods of time.

Keywords: decision making, instruction, expertise, international education

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# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# DESCRIPTION OF THESIS STRUCTURE

This thesis begins with preliminary pages introducing the contents and providing introductory information contained herein. The structure reflects the requirements for submission to the university.

The body of this thesis is a journal-ready research article entitled, *Implementing Decision-Based Learning in a Peruvian University*. It is a mixed-methods research project that investigated the experience of professors and students in a Peruvian university while implementing decision-based learning (DBL). The article's literature review incorporates the main points of the extended literature review, so there is an overlap in content.

This thesis ends with references and appendices that accompany the article. The appendices provide more context to the study. Appendix A is an extended literature review on the relationship between expertise, higher education, and decision-based learning. This literature review includes Drs. Richard E. West and Kenneth Plummer as co-authors. Appendix B provides the instruments used such as surveys, interview protocols, and the rubric used to grade professor videos implementing DBL. Appendix C includes the IRB approval letter to collect data. The primary author of this second article is Christopher Cardenas, with Drs. Richard E. West, Kenneth Plummer, and Heather Leary as co-author.

# Implementing Decision-Based Learning in a Peruvian University

People attend a university to gain knowledge and skills that will prepare them to enter the workforce (Lund, Liang, Konowitz, White, & DeSilva Mousseau, 2019). The attainment of knowledge and skills may be considered the beginning of expertise development in a specific discipline. Therefore, university professors are one of the primary resources to develop expertise in the students (Hodge, Gerberry, Moss, & Staples, 2010).

However, university professors may have difficulty transferring their expertise to their students (Bransford, Brown, & Cocking, 2000). Many professors struggle conveying their expertise because of the prevailing misconception that if one is an expert at something, then they can teach it effectively (Mazur, 1997; Travis, 1994). This, however, is not supported by the research (Bransford et al., 2000; Feldon, Timmerman, Stowe, & Showman, 2010; Nathan & Petrosino, 2003). Shulman (1986, 1987) referred to this as the difference between content knowledge and pedagogical content knowledge. Content knowledge is knowledge about the subject matter. Pedagogical content knowledge is knowledge about how to effectively teach that specific subject matter. From the student perspective, some studies suggest that university graduates may feel underprepared once they enter the workforce because their education focused more on theoretical understanding instead of on practical skills that are necessary to be effective in the ever evolving workforce (Bennett, 2017; Jang, 2016; Liebenberg, Huisman, & Mentz, 2015; Tynjälä, 2008).

In order to improve teaching expertise, Gobet (2005) suggested that if we develop "an understanding of how experts reach high levels of performance [we] could suggest general learning mechanisms, and thus help design better teaching methods" (p. 183). Bol and Garner (2011) posited that expertise may be taught more effectively by giving students a set of steps that novice students can follow in order to consider likely solutions to a problem. One possible solution that aligned with Bol and Garner's (2011) assertion is a pedagogy called decision-based learning (DBL) (Plummer, Swan, & Lush, 2017). DBL has been shown to help university students in their expertise development (Plummer et al., 2017; Sansom, Suh, & Plummer, 2019). In DBL, expert professors develop a decision map of how to solve problems within their discipline, and then present this decision map to their novice students to help them solve numerous, real-world problems. However, there is limited research on the effects of implementing the DBL pedagogy. Therefore, the purpose of this research is to explore the implementation of this new pedagogy.

The following sections introduce the concept of expertise and how experts use their knowledge. Then they review how teaching expertise may be difficult for experts. They conclude with a suggested pedagogy that may help university professors teach their expertise to their novice students more easily. The methods section then follows.

**Developing Expertise Through Conditional Knowledge**

Corporate, educational, and informal instruction are increasingly being viewed through the lens of expertise development (Barreiros & Abreu, 2017; Ellis & Smith, 2017; Elvira, Imants, Dankbaar, & Segers, 2017; Howard, 2012; Le Mire, 2016; Newell, Wu, Leingpibul, & Jiang, 2016). Bransford et al. (2000) explained that expertise is the result of successful learning, and that a distinguishing feature of experts is their well-developed conditional knowledge. Conditional knowledge is knowing the conditions under which you should perform certain tasks and employ specific skills (Oluwatayo, Ezema, & Opoko, 2017; Vasyukova, 2012). Conditional knowledge is widely accepted as an essential aspect of expertise (Amolloh, Lilian, & Wanjiru, 2018; Elvira et al., 2017; Lorch, Lorch, & Klusewitz, 1993). In other words, it is important to know *what* and *how* to do something, but the culmination of that learning may be knowing *when* and *why* to do it (Paris, Lipson, & Wixson, 1983). Amolloh et al. (2018) expounded on this by writing that conditional knowledge employs critical thinking and problem solving at an expert level, and that it can even increase one's confidence in their ability. However, being an expert and having conditional knowledge does not necessarily qualify you to teach conditional knowledge effectively (Shulman, 1986, 1987).

**Experts Struggle Teaching Conditional Knowledge**

Experts typically have difficulty teaching novices (Bransford et al., 2000), and this may be because they know something so well that their content knowledge overshadows their pedagogical content knowledge (Nathan & Petrosino, 2003). Recognizing these expert blind spots, Eric Mazur of Harvard University has developed what is known as peer instruction, because he realized that students are sometimes better at explaining new concepts to their fellow classmates than the professor (Mazur, 1997). Mazur (1997) suggests that this is because the professor has learned the concepts so long ago, and that makes it difficult to empathize with the students' misunderstanding. Experts' knowledge can become so tacit that what used to be explicit for them has become completely implicit. When something is implicit, it is difficult to unpack it explicitly for novice, concrete learners.

Another impediment that could hinder students from learning expertise is that instructors do not necessarily know the principles for teaching conditional knowledge. Meyer (2018) interviewed 16 secondary school teachers implementing a new teaching strategy that includes the elements of conditional knowledge and found that they had difficulty doing so because they did not know how (Garner, 1990). More specifically, "teachers believe they provide their students with opportunities to practice clear procedural, and observable, steps in making a decision, but are not particularly strong in supporting the students' thinking about their internal intellectual processes" (Meyer, 2018, p. 8).

**Teaching Conditional Knowledge Through Decision-Based Learning**

One strategy that helps overcome these challenges in teaching conditional knowledge is decision-based learning, a universal instructional method that can be used to teach various disciplines from STEM to arts courses (Plummer et al., 2017). This teaching method involves having professors develop a decision map for solving problems and using that to teach their students how to make expert, problem-solving decisions. Before we introduce DBL more fully, we will first examine some variations of similar pedagogies that use decision-making.

**Former approaches to decision-making in learning.** Meyer (2018) focused on decision-making as she and others embedded Challenge-based Learning (CBL) in teaching the Engineering Design Process (EDP) for faculty development training. She found that the "teachers believed they did not make clear to students why they were making the decisions and/or clarifying the potential impact of a decision" (p. 8). So, it seemed that teacher confidence in pedagogical knowledge was lacking.

Hagge, Amin-Naseri, Gilbert, et al. (2015) and Hagge, Amin-Naseri, Jackman, et al. (2017) had 373 undergraduate students take a thermodynamics activity by a computerized tutoring system using what they described as decision-based learning, in which there were significant learning gains, but it was domain-specific to thermodynamics. However, this approach was limited to thermodynamics. Law, Pittman, and Miller (2014) were recognized for developing a pedagogical strategy called decision-based learning for teaching how to diagnose and treat rheumatic diseases. Law et al. presented many difficult, fictional cases that their students had to work through in groups, with constraints like patient history and a budget. About

67% of the treatment students rated their class experience at “10” on a 10-point Likert scale, while only 35% of the control group rated their class experience a “10.” However, this approach was also limited to medicine and did not ensure individual accountability.

**A new approach to decision-making in learning.** The challenges of the aforementioned variations of decision-based learning deal with teacher confidence in pedagogical knowledge, limiting the domain of the model, and a lack of individual accountability. The version of decision-based learning that Plummer et al. (2017) developed attempts to address each of those challenges explicitly and more. This approach to DBL starts with having the professor create an expert decision model for solving problems, which looks like a decision tree (see Figure 1) that students can use to solve problems in a specific subject. This model can be distributed via paper hand-outs, presentation software, the DBL software (found on DecisionBasedLearning.com), etc.

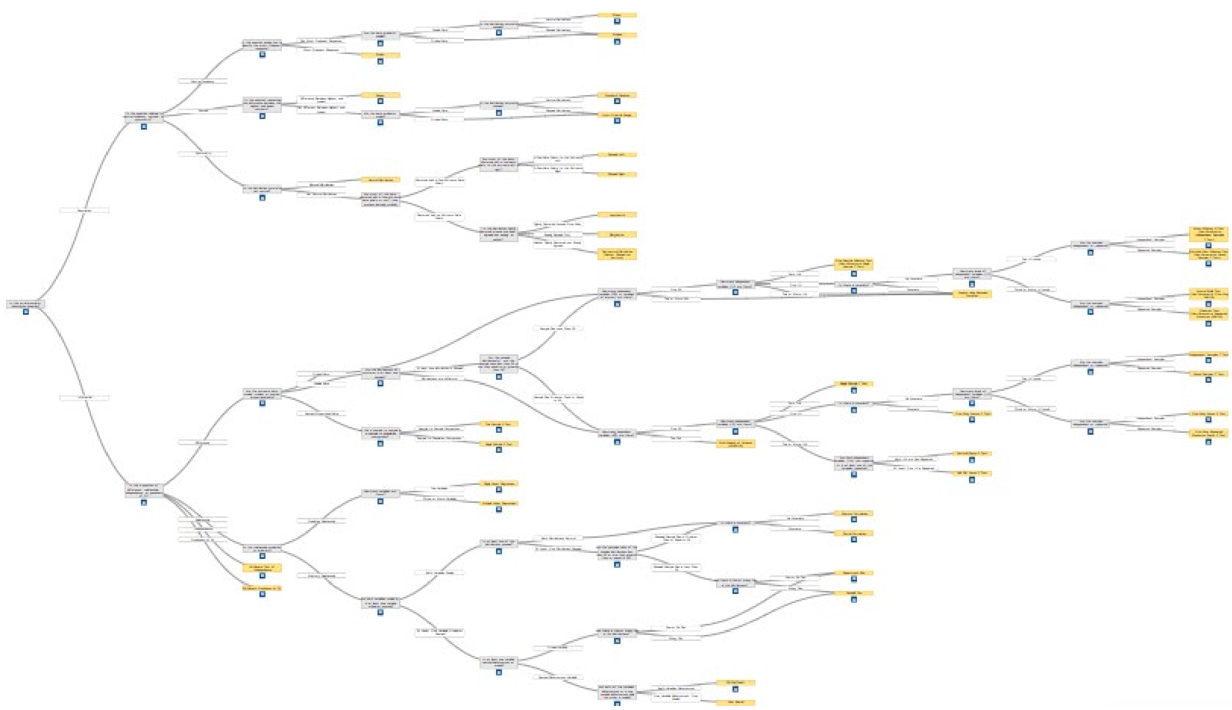

*Figure 1.* DBL Model. This expert decision model shows various decision points, options, and final courses of action.

Once the students have access to the model in class, the professor presents concrete, real-world problems that the teacher has come up with for students to solve. The professor then asks the students the question on the first decision point of the model in order to begin solving a presented real-world problem (see Figure 2). The professor presents the options for the first question and instructs the students on the new material presented in these options through what is called just-enough, just-in-time instruction. The principle behind this type of instruction is to teach only the material that is needed to decide at this specific point in the model. The teacher provides a brief definition of each option (see Figure 3), an example of each (see Figure 4), key information to distinguish each of them (see Figure 5), and a short practice for students to practice differentiating between the different options (see Figure 6). Then the professor returns to the concrete example and has the students decide which option to pursue at this decision point.

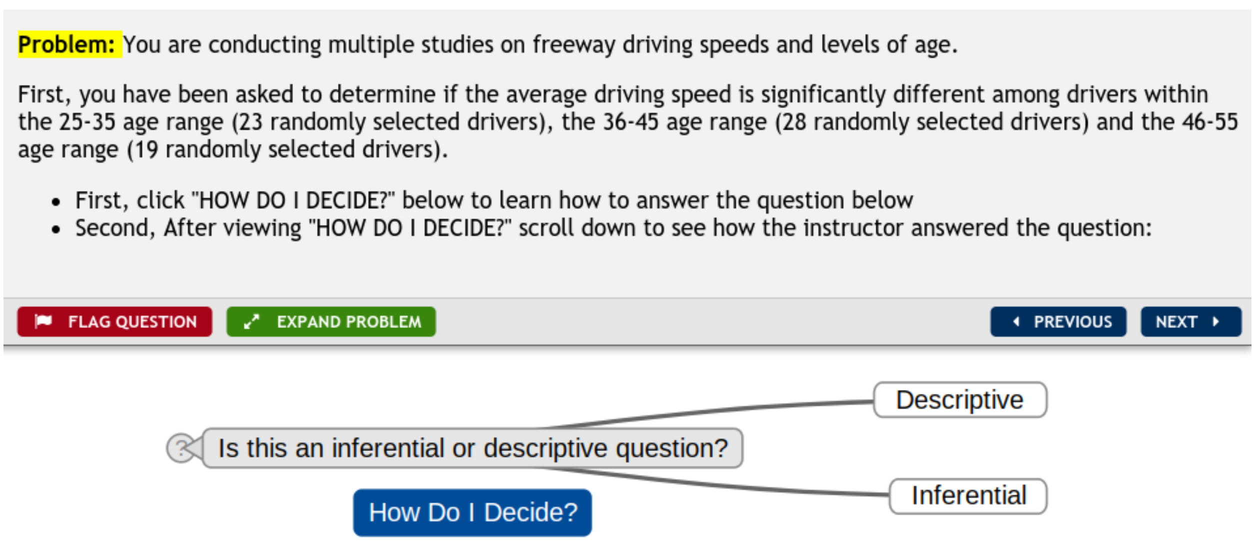


*Figure 2.* Concrete Problem. A concrete problem is presented, and the student can click on ¨How Do I Decide?¨ to receive instruction on how to make this initial decision.

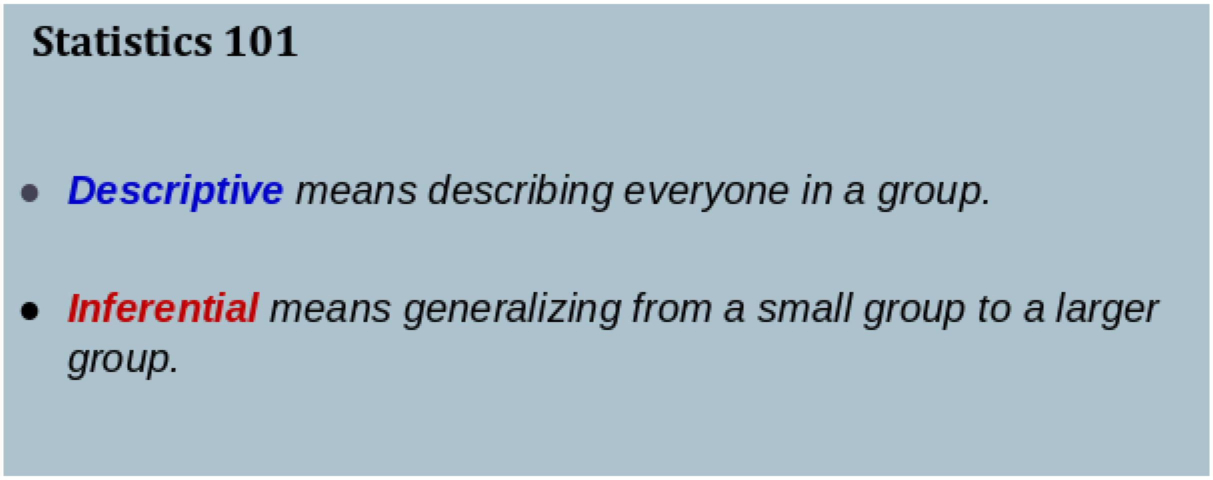


*Figure 3*. Definition. The first step in just-enough, just-in-time instruction is to define the options.

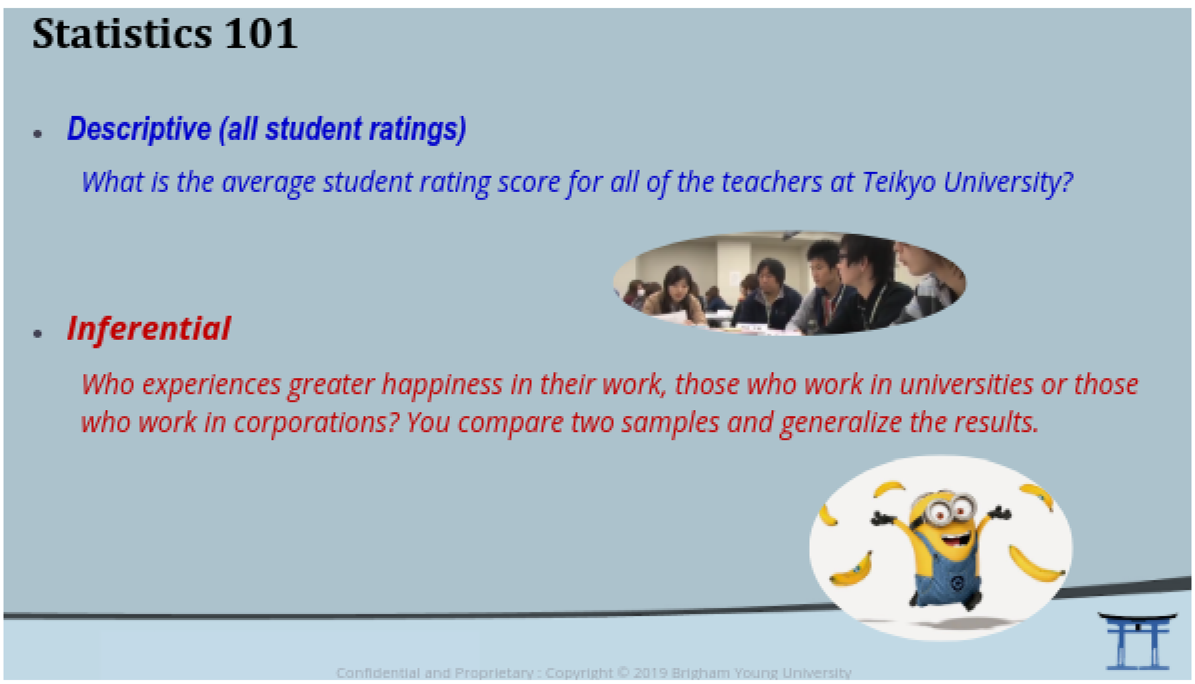


*Figure 4.* Examples. The second step in just-enough, just-in-time instruction is to provide examples of each option.

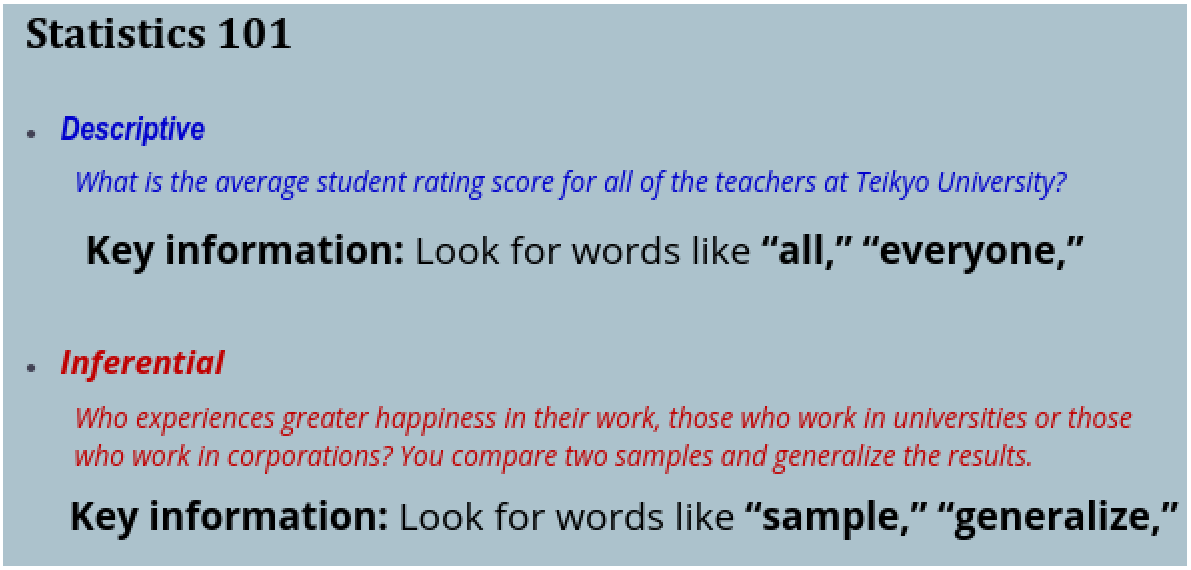


*Figure 5*. Key information. The third step in just-enough, just-in-time instruction is to provide key information that helps to distinguish between each option.

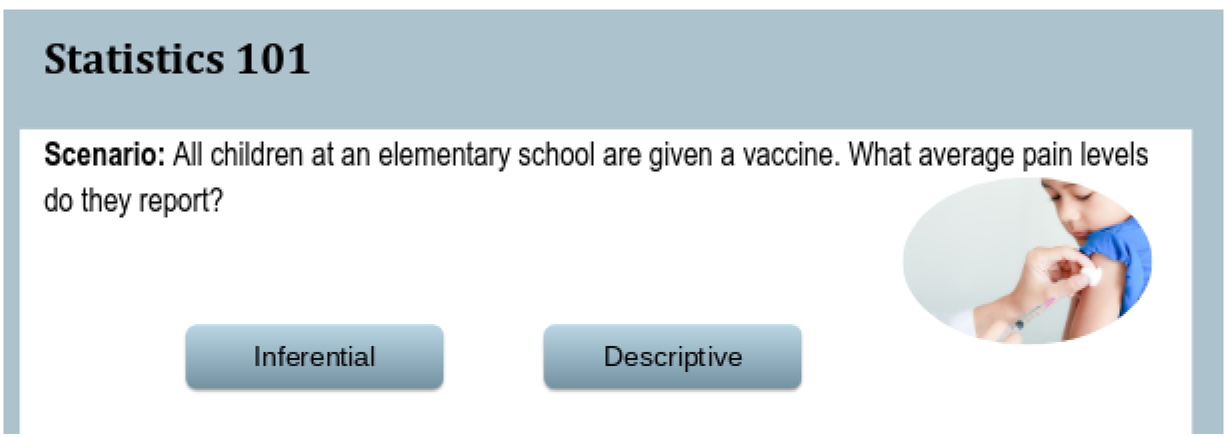


*Figure 6*. Small practice. The last step in just-enough, just-in-time instruction is to provide students practice distinguishing between each option.

Once a student chooses an option to pursue, the teacher asks the student to defend their answer by asking why they chose that option. The professor can then mediate a class debate to determine if that option is the correct one to choose or not. Once the class comes to a consensus, the professor continues with the class on the path that was determined. The professor determines how much of the model to cover each day.

Therefore, DBL may help increase professor confidence, because it is structured enough to allow the professors to follow specific pedagogical steps and create a stepwise problem-solving model for students, yet open enough to be applied to various disciplines. Additionally, once students have a copy of the model, they can use the model to go through as many concrete, real-world problems that the professor provides them, which provides a means for individual accountability. In this way, DBL can help solve the problems that emerged with the previous approaches to decision-based learning.

Sansom et al. (2019) implemented this approach to DBL in a chemistry class in order to see if the pedagogy improved academic performance on heat and enthalpy test items. The same exam was distributed to control and experimental groups of students, where the control group received the professor's original instruction, and the experimental group received the professor's DBL instruction. The control group received a test score average of 4.5, and the students who practiced five or ten DBL problems had mean differences of +0.626 ($p$=0.002) and +0.577 ($p$=0.018), respectively. Finally, as an anecdote, this approach to DBL is currently being used by over 60 professors in Brigham Young University (BYU) in varying disciplines from religion and humanities to math and science.

However, while initial studies report effectiveness from using DBL, and while the method is widespread at our university, it has had only few implementations at other locations. In addition, no research has been conducted yet on the method outside of our university. In order to better understand the generalizability and transferability of this method, it is essential for additional research to investigate the challenges and successes of implementing the methodology elsewhere. In this paper, we report research into one such implementation that has the benefit of not only being outside our university, but international, allowing us to better understand the potential breadth of applicability of the method.

# Method

This research was conducted with faculty at a university in Peru, where we sought to answer the following research questions:

1. How effectively can professors in a Peruvian university implement DBL?
2. What benefits and challenges do professors perceive from implementing DBL in a Peruvian university?
3. How did using DBL as a homework strategy affect student learning?

We now discuss the design and context of the research, what sources of data were collected, and how the analyses were conducted for each type of data collected. Additionally, we explain how we have established rigor and trustworthiness, as well as discuss the limitations of the study.

## Research Design

We employed a triangulation mixed methods approach as explained by Creswell and Plano Clark (2017), which is where we collect both qualitative and quantitative data in order to better understand the experience of implementing DBL at a university in Peru. This method was chosen because it is specific enough to focus on the research questions, yet general enough to be open to what qualitative and quantitative data may reveal. We relied more on qualitative data than on quantitative data.

In order to answer the first research question, we collected 74 implementation videos across all three workshops. In order to answer the second research question, we surveyed 42 professors and interviewed 5 professors. In order to answer the last research question, we gathered qualitative and quantitative data. We studied one professor (pseudonym: Jane) who implemented the DBL software as a homework strategy. She was teaching two sections of the same course, so she used one section as a control group and the other section as the DBL experimental group. She used a quiz to measure the difference in academic achievement between the two groups. We then surveyed 34 students and interviewed 2 students, all from the DBL experimental group. So, we will answer the last research question in two parts: a quantitative measure of learning through academic performance, and a qualitative measure of learning through surveys and interviews. Table 1 organizes which data sources answer which research questions.

Table 1

*Research Questions and their Data Sources*

| Research Question | Data Sources |
|---|---|
| How effectively can professors in a Peruvian University implement DBL? | 74 Videos of Faculty Implementing DBL |
| What benefits and challenges do professors perceive from implementing DBL in a Peruvian university? | 42 Professor Surveys<br>5 Professor Interviews |
| How did using DBL as a homework strategy affect student learning? | 34 Student Surveys, 2 Student Interviews, and Quiz Score Analysis, all from one instructor (“Jane”) |

**Research Context**

The Universidad Nacional de San Agustín [Saint Augustine National University] (UNSA) is in Arequipa, Peru. In August 2018, we were invited to perform a DBL workshop for UNSA professors. This workshop was carried out for four consecutive days for four hours each day. The instructors consisted of three professors, one educational consultant, and one graduate student. There were about 25 professors in regular attendance. This workshop was then repeated in March 2019, with about 20 professors in regular attendance, and November 2019, with about 34 professors in regular attendance.

The schedule for the DBL workshops consisted of some instructional lecture time each day, with most of the time being spent on helping professors in small groups create their own DBL models for their classes. The professors were given one month after the end of each workshop to submit a video of their implementation of DBL. Professors were given an implementation fidelity grade based on the fidelity of their execution of the DBL pedagogy based on the following eight steps: present the purpose of the course, present how DBL will help accomplish the learning objective, present a concrete example of a problem to be solved or something to be evaluated, present the first decision point with its options, provide just-enough-just-in-time instruction, provide at least two practice examples, return to the original concrete example to choose an option, and repeat until you reach the end of the model. In order to determine whether their instruction was concise enough to qualify as "just-enough-just-in-time," we gave them the following structure: define each option, give an example of each option, provide key information that distinguishes each option from the others, and provide a small practice for students to distinguish one from the others.

Peru represents an ideal region to have studied this DBL implementation because Peru is intent on improving their education. Peru has a significant skills gap compared to most developed countries (Organisation for Economic Cooperation and Development [OECD], 2016). Additionally, there is a cognitive skills gap between upper- and lower-class Peruvian students (Castro, Yamada, & Arias, 2016; Huaman, 2013). Since the Peruvian government recognizes the economic disadvantages from these gaps, they have been making large, monetary investments in improving their educational system for the past 12 years ("Investment in education increases in

Peru as reforms gain momentum," n.d.). Thus, Peru represents an ideal region for having studied this DBL implementation, because Peruvian universities have the support systems in place from government and university leaders for a quality implementation.

**Participants**

Professors who completed any of the three workshops were invited to take the survey, so 104 professors were invited. Their disciplines ranged from arts and literature to architecture and statistics. Of those invited, 42 took the survey. The five professors who were interviewed were ideal interviewees because they achieved high implementation fidelity scores [ranging from 6 to 7.5 (75% to 94%)]. As a reminder, the implementation fidelity rubric consisted of eight steps: present the purpose of the course, present how DBL will help accomplish the learning objective, present a concrete example of a problem to be solved or something to be evaluated, present the first decision point with its options, provide just-enough-just-in-time instruction, provide at least two practice examples, return to the original concrete example to choose an option, and repeat until you reach the end of the model.

The professor who used DBL solely as a homework strategy approach, Jane, was ideal because she received an implementation fidelity score of 94%, and she showed particular interest in using the DBL software by asking for weekly instruction on how to use it. In other words, even though she only used DBL as an out-of-class homework strategy, we were confident in her ability to develop a pedagogically sound decision model in the DBL software. The lead researcher met with Jane individually seven times over a 12-week period through video chats to help her develop her model in the DBL software and align it with the learning outcomes of the quiz. This quiz helped to measure any academic achievement differences between the control group of students who do not use DBL, and the experimental group of students who do use DBL.

Lastly, of Jane's students who used the DBL software, 34 students took the student survey and 2 students were interviewed.

**Data Collection**

We collected the following data sources: 74 implementation videos, 42 surveys from professors, 5 professor interviews, 34 student surveys, 2 student interviews, and quiz scores between Jane's DBL and non-DBL sections. All interviews were about 15 minutes in length.

The implementation videos were required for professors to complete their participation in the DBL workshop. The professors recorded their implementation in class and emailed us video files or YouTube links (if their video files were too large to send over email). We distributed a Google survey to all participants in the workshop with 42 professors completing the survey. The five professor interviews were recorded and transcribed. We distributed Google surveys to all of Jane's students in her two sections, with 34 responding. The two student interviews were recorded and transcribed. All the questions for both surveys and both interviews can be found in Appendix A. Jane emailed us the quiz scores for both her control and experimental groups.

**Data Analysis**

The implementation videos were analyzed utilizing the eight-step rubric we gave them. We gave them one point if they clearly performed the step, half of a point if they somewhat performed the step, and no points if they did not perform the step at all. There was a total of eight points, and their percentages were averaged together.

We analyzed all survey and interview responses using thematic analysis as described by Braun and Clarke (2006):

1. Familiarizing yourself with the data by reading through all the transcripts
2. Generating initial codes that collate the data

3. Searching for themes and provide initial descriptions of the data
4. Reviewing themes and create a thematic map of the data
5. Defining and naming the themes to be as inclusive as possible
6. Producing the report

This was an appropriate analytical method because our qualitative data was open-ended in nature. We determined themes based on prevalence (how many times it appears) and relevance (how important it was to help answer the research questions). We relied more on the semantic, or explicit, messages rather than on the latent, or implicit, messages in their responses.

An independent samples *t* test was performed on the quiz scores between Jane's control and experimental groups. There were 25 students in the DBL section who took the quiz, and 34 students in the non-DBL section. There were fewer than 30 students in the experimental DBL group, but their scores were not significantly skewed, so normality can be assumed. All the students were 2$^{nd}$ year, mechanical engineering students. With the help of a BYU professor of the same discipline, we helped Jane revise her quiz to make sure it was aligned with the learning outcomes of the course by comparing each question with the learning objectives and subjectively determined that they were aligned. Jane used the learning objectives in order to construct the DBL model, so by ensuring that both the DBL model and the quiz are aligned, it ensured that the quiz had sufficient face validity as a measurement of the learning with the DBL method.

**Rigor and Trustworthiness Considerations**

To strengthen our claims of rigor and trustworthiness consideration, we applied prolonged engagement, triangulation, peer debriefing, negative case analysis, progressive subjectivity checks, and member checking.

Our prolonged engagement with the professors consisted of the DBL workshops, where we were able to develop a personal relationship with the participating professors over five days. The lead author participated in seven, 1-hour, video chat meetings with Jane throughout 12 weeks, followed up with weekly emails. During the video chat meetings, he would offer feedback on Jane's work and provide guidance on what she should work on next. The triangulation of multiple data points consisted of video implementations, surveys and interviews from professors and students, and quiz scores.

For peer debriefing, we had a non-biased, third party evaluate our "methods, emerging conclusions, biases and so on" (Williams, 2018) in order to promote honesty and accuracy. This third-party peer agreed with our methods. The third-party peer criticized the found themes causing us to reorganize data and reduce the number of themes. We also performed a negative case analysis of our themes and conclusions. We proposed a hypothesis opposite of our conclusions and scanned the data for confirmation of that opposing hypothesis, in order to consider alternative perspectives and promote accuracy. This reduced our number of themes and caused us to reorganize the data even more.

Progressive subjectivity checks were performed through the research log kept on a Google document. This research log served as an audit trail of our thoughts, biases, and expectations to help perform subjectivity checks. It also helped to provide more context for the findings and insights from other data sources. The lead author included spontaneous reviews of meetings with Jane, reactions to data analyses, any unexpected occurrences, and personal thoughts and biases. This may help us understand why people responded the way they did and provide context that gives reasoning to their responses, instead of reporting isolated quotations from responses. Finally, we performed member checking, where the professor and the students checked our analyses and conclusions via email and WhatsApp in order to determine whether we accurately explained their experiences.

### Limitations

We prepared Jane beforehand to be conscientious of the Hawthorne effect, but we had no way of controlling for a Hawthorne effect. Thus, it is possible that she may have emphasized teaching in a different way in the experimental group over the control group. Another limitation that was evident was the lack of a physical presence at the UNSA. We could not physically be there in the UNSA beyond teaching the workshops. However, the regular video chats helped to alleviate a lack of physical presence.

## Findings

The findings are presented according to the three research questions. This section describes the findings of our data analyses. The three types of analyses performed were (a) evaluating the implementation fidelity through videos, (b) analyzing the qualitative data through Braun and Clarke's (2006) thematic analysis method, and (c) performing statistical analysis on the quiz score data.

### How Effectively the Professors Implemented DBL

The average percentage of implementation fidelity for all the professors from the three workshops was 72%, and the median percentage was 75%. The most important areas on the rubric were steps 3-7, because they deal with leading the students through an efficient use of the model. Of those steps, the step titled "provide at least two practice examples" had a low fidelity percentage of 22%, which was 2.3 standard deviations from the mean. This suggests that UNSA professors consistently struggled at providing practice examples to help students differentiate between options. Excluding this low-fidelity step, the implementation fidelity would be 79%.

Since no pedagogical method is usually implemented with 100% fidelity, the average and median fidelity percentages are overall acceptable.

**Benefits and Challenges for the Professors**

After performing the full thematic analysis, multiple themes were identified. These themes were identified through the combined results of both professor surveys and interviews. For the professor benefits, we identified four prevalent themes from the surveys and interviews: the practicality of the method, its impact on learning, the impact on teaching, and benefits that they felt specifically from creating a decision model. Practicality refers to how practical the pedagogy felt to them. Ten professors reported benefiting from the practical focus on real-world problems and how DBL can be implemented individually and in groups. Thirteen professors reported that it was practical in engaging the students because it is not “boring” and requires students to participate.

The impact on learning refers to the effects on the learning process. Ten professors reported a perceived increase in student cognitive abilities, such as “critical thinking,” “reasoning skills,” and “creativity.” Four professors believed that students increased in their understanding of the material by “solidifying their knowledge,” and “reflecting on what they are thinking.” The impact on teaching refers to the effects on the professors’ pedagogical efforts. Four professors reported that their DBL provided a structure that facilitated how to “organize the lecture.” Three professors reported that they benefited from the “focus on the learning outcomes.” “Benefits of decision model” refers to the benefits of the decision model. Three professors praised how the model “breaks down the problem-solving steps” into small, manageable pieces. Three other professors praised how the model can be used with “various problem conditions.”

One professor who was interviewed (pseudonym: Juan) is an experienced professor who teaches in the medical school. Juan reported that his first impression of DBL pedagogy was that it was a novelty, and that his students were eager to participate in this new teaching method. They were all interested in interacting with each other while using the software, because Juan planned to use the DBL software as the delivery platform. Juan said that his students were intrigued to learn with this new pedagogy.

After a high-fidelity implementation, Juan reported to have benefited from basing his instruction on problem feature identification. He felt that DBL allowed him to focus on helping his students identify key elements of a problem which indicate what type of solution to pursue. According to his analysis of his students, this helped the students synthesize what they needed to know and apply it more easily. He noticed this change in the way they responded to his questions and the problems he presented.

Another experienced professor who was interviewed (pseudonym: Rosa) teaches a research-related class. Rosa's first impression of DBL was that it might be difficult to grasp, but that it was worth a try. Rosa felt that preparing a DBL class required her to think more deeply about the content in order to organize it well into a decision model, which she prepared in PowerPoint. After a high-fidelity implementation, she reported benefiting from how the pedagogy helped her organize and partition the content. She noticed that this made it easier for her students to see how different topics related to each other, or how they did not relate. Rosa also reported that the pedagogy helped elicit more engagement from the students. She contrasted this engaging, DBL style of teaching with the way she used to perform "monotonous" lecture.

The third experienced professor who was interviewed (pseudonym: Mercedes) teaches a research-related class involving field work. Mercedes reports feeling scared to attempt this pedagogy with her students. She implemented DBL using a PowerPoint presentation in which she developed the decision model and activities. After a high-fidelity implementation, she reported that this pedagogy helped her students act upon what she was teaching when she had them perform their own research projects. Mercedes said that the pedagogy was more “dynamic” in showing the students the differences between concrete problems in order to convey the theories, instead of going through the theory alone.

The fourth experienced professor who was interviewed (pseudonym: Sonia) teaches a science-related discipline. Sonia usually rejected teaching through lectures, and she explored alternative pedagogical approaches to help her involve her students more during class. Thus, Sonia’s first impression of DBL was that it was another pedagogical tool she could use to help her involve her students more during class. She implemented DBL with paper cut-outs of the different decision points that constitute the whole decision model. Sonia would put the paper cut-outs on the whiteboard and go through the decision model with her students in that way.

After a high-fidelity implementation, Sonia reports that her students reacted positively to having decisions to think between for the different questions Sonia posed in each decision point. One of Sonia’s students eventually responded, “I see what you’re trying to do, you’re trying to make us think about why we do what we do when we solve problems!” Another benefit that Sonia reported by using DBL helped strengthen her teaching by providing another way that she can focus on the learning outcomes. She said she could do this because the only way to create a meaningful decision model was to make the decision points lead to a learning outcome.

Lastly, the fifth experienced professor who was interviewed, Jane, taught a math-related course. Her first impression of DBL was that she was afraid to attempt it. However, shortly after beginning the workshop, she wanted to develop her decision model using the DBL software.

After a high-fidelity implementation, she reports that one benefit was that her students could use this decision model repeatedly in order to engrain the model into their own ways of thinking. She felt that this repetition helped her students without Jane herself needing to be there. Additionally, she noticed that her students put in more effort while learning with DBL, as if they were more engaged.

The professors also noted some challenges in using the DBL method. We identified two prevalent themes from the surveys and interviews: challenges with preparing the materials for DBL and challenges with executing the pedagogy. For the main challenge of "preparation," 27 professors reported struggling with the amount of time and effort that developing their decision model took. Twelve of those professors reported specifically struggling with knowing "what questions to put where," as well as how to divide their material into pieces to put them onto a model. Four reported struggling to develop a well-developed problem bank. These challenges may explain why the lowest aspect of their implementation was creating practice examples for the students, and this is an area where future development of the method could improve through better scaffolding of this aspect for the professors.

In addition, 18 professors reported struggling implementing the pedagogy in their classrooms. Eleven of those professors reported that they would have liked "help and practice going through the steps of the pedagogy" before implementing it. Two of the eighteen professors reported that they would like more time to understand the reasoning behind the pedagogy.

Juan, one of the professors interviewed, reported that he struggled to create efficient "just enough, just in time" instruction. He said that for him, it would be easier for his class to learn the theory prior to coming to class and going through the DBL application and analysis of problems. Jane reported that it took more time and effort than she expected to put into this, and that it was difficult to balance this with other priorities she has as a professor. She took a little over a month to develop her first implementation. Rosa, Mercedes, and Sonia reported difficulties not with the pedagogy, but with the interface of the software and the lack of internet access.

**Effectiveness of DBL as a Homework Strategy**

The 34 student surveys and 2 student interviews were conducted with students from Jane's class, when she only used the DBL software as a homework strategy in preparation for a quiz. These surveys and interviews provided qualitative data for answering the last research question of how the DBL homework strategy affected student learning. For the student benefits, we identified three prevalent themes: feedback on mistakes, impact on learning, and benefits related to the use of the decision model. The main student benefit was the feedback on mistakes. Nineteen students responded that DBL helped them recognize the specifics of their erroneous thinking by identifying the specific decision point they were misunderstanding. Eleven of those students reported that they benefited from "correcting my mistakes" because the mistakes were identified. One student mentioned that you can resolve concerns without anyone being present, and another said that DBL makes it easier to know what you need to study more.

The second biggest benefit to students was the impact on learning. Eighteen students reported experiencing learning gains, with 13 of them saying they understood the material more and five of them saying that they learned "faster and easier." The third biggest benefit to students were benefits related to the use of the decision model. Five students benefited from how the model breaks the material down into "small, ordered steps," and six students reported that they could use the same model to solve various problems. One student appreciated that you can "measure your own level of learning."

In Jane's interview, she reported that the students were excited to work on this new pedagogy as a homework strategy. One student who was interviewed (pseudonym: Student A) reported that DBL helped him measure his own level of understanding for the material. He said that he realized what he did understand from the curriculum up to that point, and what he needed to improve on. Another student (pseudonym: Student B) reported that the visual aspect of the pedagogy made it easier to understand. He was able to follow along the material more easily by following the decision model. Both students also reported that, according to their perspectives, the rest of their classmates benefited from learning through DBL.

For student challenges, we identified two prevalent themes from the surveys and interviews: DBL required more effort and the novelty of the pedagogy was challenging. For the biggest challenge of requiring more effort, four students responded that they needed to make a more concerted effort to learn. Three of them explained how they had to think more about the material to choose the correct option, and the other one felt that he/she was going too slowly through the model. For this reason, it could be that the benefits they reported in learning above, were due more to the increased attention to their learning that DBL required, rather than to the uniqueness of the method itself.

For the second biggest challenge about the novelty of the pedagogy, three students expressed that the novelty of this approach was an impediment to their learning. They did not report anything more than needing to "get accustomed" to a new "style" of learning. Therefore, it seemed that these responses may be related to the previous theme of requiring more effort because this new "style" may be a challenge in that it requires more effort.

Lastly, the following statistical analysis was performed in order to provide more insight into answering the last research question from a qualitative measure of learning, that is, the difference between quiz scores. An independent samples *t* test was conducted on the quiz score data, using SPSS. Since the sample size of the experimental group was 25, we measured the skewness (.204) and the standard error of the skewness (.464). This verified that there was no statistically significant skewness, because the *t* ratio between the skewness and its standard error of skewness was less than two (i.e., an approximate *t* critical for an alpha value of .05). Thus, the assumptions were met to use an independent samples *t* test, because the ratio between the skewness and its standard error was less than two, which validated the use of an independent samples *t* test. The mean quiz score values for the control and experimental groups, respectively, were 6.235 and 9.360. The *p* value of the test was 0.002. Therefore, there appeared to be a statistically significant difference between the means, supporting the hypothesis that DBL had a statistically significant impact on improving academic achievement. This analysis was exploratory in nature.

In the interview with Jane, she reported that it was difficult to get some of the students to cooperate with the new pedagogy. Some of the students were resistant to trying out the new pedagogy. Student A reported that he liked how DBL helps you identify what you chose incorrectly but also recognized that it didn't tell you why you were wrong. That meant that when he went back to correct himself, he didn't have any additional help to correct his decision-making other than knowing that the previous decision he made was incorrect. Student B reported similarly that you can go through the model and not necessarily know why you got something incorrect, thus not learning. He personally guessed at a few of the decision points and when he got them correct, he didn't know why. So, they struggled with understanding why their decision was correct or incorrect.

## Discussion and Recommendations

The results of this study were somewhat unexpected. Some results supported our beliefs about the DBL method, and some results refuted them. As recorded in the research log, what was expected was that both professors and students would benefit most from using multiple concrete examples to help convey and understand the subject matter. This was proven incorrect because professors felt the pedagogy was generally practical for its different components, and students felt that recognizing your mistakes was most valuable. However, it was also expected that professors would struggle with the amount of preparation that DBL requires and that was what the professors responded. The triangulation of multiple data sources helped to reveal more of the implementation experience. Overall, the results of this study were unexpected and insightful.

### How Effectively the Professors Implemented DBL

Considering that the average percentage of the implementation fidelity was at 72% and the median percentage was 75%, we felt that their implementation fidelity was at an acceptable level. Additionally, the implementation of each of the professors varied in terms of skill level. Some were able to implement it very well, and some were not able to implement the pedagogy correctly. One professor mainly lectured during the whole class, while going through the model without interacting at all with the students. Another professor asked questions and fostered discussion with the students while expounding from the model. The recommendation we suggest for future implementations is to ensure a professor understands the interactivity aspect of the pedagogy, in order to ensure a high implementation fidelity.

Additionally, we realized that there was a certain essence of the implementation that distinguished high fidelity implementers from the low fidelity ones, and that was not explicitly mentioned in the rubric. We best described this essence as “fostering discussion.” The professors who fostered discussion between themselves and the students, seemed to implement the DBL pedagogical steps with more fidelity. Professors who fostered discussion well received implementation fidelity scores of 75% to 92.5%. Professors who did not foster discussion well received implementation fidelity scores of 22% to 50%. Therefore, we recommend considering an emphasis on fostering discussion as an essential component of the DBL pedagogy that should be taught to those implementing the method.

**Benefits and Challenges for the Professors**

For the professors, the main benefit was the practicality of the method. Ten professors focused their responses on using real-world problems, which implied that they might not currently be emphasizing real-world applications in their classes. We recommend continuing to focus on this in the future. While it is possible to focus on real-world applications without the DBL method, and professors who do so could find similar benefits, it seems that DBL was appealing to professors as a simple, systematic way to make real-world applications with the material they were teaching.

Ten professors noted a second benefit that they perceived the students to gain improved cognitive abilities, such as improving their logic, reasoning, and creativity. These types of responses support the idea that DBL provides mental maps that not only help students decipher how to solve problems on that material, but it may also improve their conditional knowledge of how to think about problems logically, according to the principles they learned. Future research could specifically look at this issue through testing of the students' conditional knowledge abilities, to measure its growth.

The professors' responses imply that professors are looking for an efficient way to systematically teach their material. Their responses focused on how DBL provides a structure to help professors organize their lectures, and how the decision model helps simplify the subject matter into more manageable steps. This seemed to be an underlying need that the professors found was satisfied.

The professors' biggest challenge with the DBL pedagogy was preparation to use the method. The research log included records from each workshop recognizing that professors seemed stressed when spending days on their decision models with little progress. Twenty-seven professors expressed that it took too much time to develop the DBL materials, especially since they only implement it for one to three days in their classes. Professors seemed to view the week-long workshop (in addition to some individual consultations after the workshop) as their input of work, and their output seemed to be defined by the short time that they implement it. Preparation time and effort may be a hindrance for future DBL implementation and perpetuated implementation. Therefore, it is recommended that solutions to this problem be investigated, because it is the main barrier to implementation.

Their particular emphasis on the difficulty creating the decision model may imply that they had trouble understanding the theoretical foundation of the model, finding a way to break down their problem-solving strategies into smaller steps, or having enough mastery over the material to feel comfortable enough to create a decision model (which one professor admitted). It may be beneficial to help professors with this aspect of implementing DBL, since the model is the crux of the pedagogy. Therefore, it is recommended that emphasizing the ideological foundation of the DBL model more in the workshop may be helpful.

The professors' second biggest challenge was executing the pedagogy. In addition to the 11 professors who expressed that they would have benefited from practicing the pedagogy more before they implemented it in their classrooms, there were two professors who expressed that they felt a lack of confidence and self-efficacy during the implementation. Therefore, the recommendation for this concern is to provide a way for professors to practice executing the DBL pedagogy and build their confidence before implementation.

**Effectiveness of DBL as a Homework Strategy**

The following discussion was based on the qualitative data provided by the surveys and interviews. The main benefit the students experienced was feedback on their mistakes. Eighteen responses emphasized how they were able to identify their own mistakes and correct them. This implies that they may have been undergoing problems with identifying their own level of understanding when they normally perform their homework. It is possible that when they normally do homework, they do not experience immediate feedback to guide them, which would create a contrast to their experience with the DBL software. This implies that the regular lack of feedback may be the biggest problem that the DBL software solves.

The themes of feedback on mistakes and benefits of the decision model may have led to the positive impact on learning. Student responses about being able to correct their mistakes in the moment, as well as breaking down the material so that they are smaller, problem-solving steps imply that these pedagogical strategies may have caused an improvement in learning.

The main challenges for the students were that the method required more effort and that the pedagogy was novel. This seems to imply that the current way students learn may not require as much effort. The responses from these six students imply that they are required to think more and synthesize their understanding of what they learned in class. Thus, DBL may be a new pedagogy that requires students to study and understand more. Therefore, it is recommended that professors prepare students that this approach may require more effort on the students.

From the quantitative perspective, the students who participated in the experimental group outperformed the students in the control group. While this statistical analysis was exploratory in nature it provides initial evidence of DBL's effectiveness. Future studies should be performed in order to support or refute this exploratory analysis.

## Conclusion

In conclusion, this study was conducted to understand different aspects of implementing decision-based learning, a strategy for developing student expertise through a focused instruction of the conditional knowledge needed to make expert decisions within a domain. To study this method, we collected data from 74 Peruvian professors who taught DBL for the first time after learning the method in a one-week workshop. The qualitative data revealed both expected and unexpected results that inform future research on and development of the DBL pedagogy, workshop, and software. Video data suggests that overall, most professors implemented the method to a sufficient level. This indicates that the method can be successfully taught quickly with a single week-long workshop.

Professors felt that DBL is a practical pedagogy that fosters student learning, but that DBL takes too much time and effort to prepare in order to be worth deeper implementation. Students felt that the DBL software helps improve understanding of the material by helping them correct their mistakes, but that it requires more effort than they expected. The quantitative data supported the hypothesis that student learning did significantly improve with the DBL pedagogy, even when implemented solely as a homework strategy. It is likely the benefit would be even greater if implemented as a classroom instructional activity with discussion.

Our recommendations for those interested in using the DBL method include ensuring that interactivity and fostering discussion are emphasized when executing the pedagogy, as well as to practice executing the pedagogy before implementing in the classroom. Additionally, solutions to reducing the amount of time and effort required to prepare a DBL implementation should be explored. Lastly, students should be prepared that using the DBL software as a homework strategy may require more effort than they may be accustomed to.

A concluding theme that emerged from this research was that DBL requires more (from professors and students) in order to gain more. It requires more time and effort in preparation from the professors in order to have a digital pedagogy that improves student learning and can be reused each semester. It requires more effort from the students to be more cognitively engaged in the problem-solving process in order for them to correct their misunderstandings and improve their learning. However, more research on DBL's effectiveness and its effects on professors and students should be done in order to better understand this pedagogy.

It is recommended that future research include replicating Jane's study but as a more in-depth implementation, such as effectuating the in-class pedagogy for a full semester. This long-term investigation can explore research questions such as what additional support can be given to professors in a long-term implementation, and whether the challenge of preparation is a one-time investment that makes perpetuated implementation more worthwhile. It would also be beneficial to see how DBL is implemented across other settings and cultures.

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APPENDIX A

## Extended Literature Review

People attend university to gain knowledge and skills that will prepare them to enter the workforce. This knowledge and skill are the beginning of their journey as emerging experts. Therefore, university professors are students' initial resource in developing expertise. However, professors may find it very difficult to be the type of resource required to engender practical expertise in their students.

The problem that this literature review investigates is the struggle that many university professors must transfer their expertise to their students. Many professors struggle conveying their expertise because of the prevailing misconception that if one is an expert at something, then they can teach it effectively (Mazur, 1997; Travis, 1994). This, however, is not supported by the research (Bransford, Brown, & Cocking, 2000; Feldon, Timmerman, Stowe, & Showman, 2010; Nathan & Petrosino, 2003). In other words, the expertise to solve problems within a discipline does not entail the expertise to teach that discipline. Shulman (1986, 1987) referred to this as the difference between content knowledge and pedagogical knowledge.

Once this misunderstanding is recognized, then it becomes evident that this negatively affects the students in the following ways. Some studies suggest that university graduates may feel underprepared once they enter the workforce because their education focused more on theoretical understanding than on practical skills that are necessary to be effective in the ever-evolving workforce (Bennett, 2017; Jang, 2016; Liebenberg, Huisman, & Mentz, 2015; Tynjälä, 2008). The pedagogical practices of having professors lecture about concepts and having students do homework out of textbooks does not prepare students well for most fields in the workforce (Bransford et al., 2000; Gobet, 2005; Prince & Felder, 2006; Shand, Glassett Farrelly, & Costa, 2016).

Plummer, Swan, and Lush (2017) claim that a newly developed pedagogy called decision-based learning (DBL) holds promise in empowering professors to help students develop greater expertise before they enter the workforce. DBL involves helping the expert professor develop a mental map of how he/she solves problems within a discipline, and then using this map as a guide to help novice students develop their own expertise. The students use this map to solve numerous, real-world problems, and the map acts as a scaffold to their problem solving, thus developing expert thinking within the students. This paper synthesizes the literature on why DBL may be an appropriate solution for many university professors.

## Literature Review

There are two problems that this literature review addresses, and one problem contributes to the cause of the other. The first is that many university professors struggle to teach expert, career skills effectively (Bransford et al., 2000; Nathan & Petrosino, 2003; Travis, 1994), and the second is that many students do not develop enough skills to be effective in the workforce after graduation (Bennett, 2017; Jang, 2016; Liebenberg et al., 2015; Tynjälä, 2008). The relationship between these two problems may not necessarily be causal, but they may be linked together in the perspective of developing expertise.

In order to address these problems, I will review the literature on developing expertise and how it relates to higher education. The study of expertise development may provide insight into what pedagogical practices may foster expertise. This may provide a basis upon which we can infer insights that would inform university pedagogical practices. I conclude by explaining how the DBL method of teaching expertise may benefit both university professors and students.

Essentially, I attempt to answer the question of how professors can effectively transfer expertise to their students.

**Learning Begets Expertise**

Learning is a process that can be defined simply as acquiring, organizing, and applying knowledge. Yilmaz (2011) said the following:

The cognitive school views (a) learning as an active process "involving the acquisition or reorganization of the cognitive structures through which humans process and store information" and (b) the learner as an active participant in the process of knowledge acquisition and integration (p. 205).

As one gains knowledge, they increase their ability to integrate that knowledge and develop skills. As one practices this application of knowledge, and learns to function with that knowledge, then one becomes an expert. In fact, Bransford et al. (2000) stated that expertise is the result of successful learning. Therefore, we can conclude that the more you can integrate what you learn into useful abilities that can benefit others, the more you become an expert.

Any time there is a teacher-learner interaction, the setting can be viewed as the teacher fostering expertise in the learner. Indeed, it can be said that learning, or converting knowledge into useful abilities and skills, leads to expertise (Bransford et al., 2000). I will now discuss the relationship between knowledge and expertise more deeply, beginning by reviewing the different types of knowledge.

**Types of Knowledge**

Researchers agree that there are three types of knowledge. While the bulk of the literature supports the general ideas represented in each of these types of knowledge, their names vary but their core meanings are essentially the same (Johnson, 2005; Plummer et al., 2017; Tynjälä, 2008; van de Wiel, 2017). In this paper we will use the names conceptual knowledge, procedural knowledge, and conditional knowledge.

**Conceptual knowledge.** Conceptual knowledge can be described as the knowledge of "what" you know (Turns & Van Meter, 2011), the concepts and theories one learns (Barrotta & Montuschi, 2018), or simply knowing "about" something (Azevedo & Aleven, 2013). Conceptual knowledge has also been referred to as declarative knowledge (Sugiharto, Corebima, Susilo, & Ibrohim, 2018), general knowledge (Barrotta & Montuschi, 2018), and theoretical knowledge (Elvira, Imants, Dankbaar, & Segers, 2017; Tynjälä, 2008). Although there are nuances to what conceptual knowledge is, there seems to be a consensus that it is an abstract and a foundational knowledge within a discipline.

Conceptual knowledge is important because it helps people develop a mental foundation of theoretical understanding within a discipline that helps them design solutions for a wide array of problems within that discipline (Alamäki, 2018; Barrotta & Montuschi, 2018). One reason why this may be the case is that concepts can help explain patterns that are found among problems of that discipline (Barrotta & Montuschi, 2018; Greca & Moreira, 2000; Vasyukova, 2012). For example, an architect knows what to look for in a high-quality design because he/she knows the guiding concepts of what to look for, such as stability of materials, foundational strength, and weathering conditions in the area. Likewise, a radiologist may know how to examine an x-ray because he/she has mastered the concepts of human anatomy, such as what the shapes and sizes of bone structures are supposed to look like.

**Procedural knowledge.** Building from conceptual knowledge, or "what" you know, procedural knowledge is the knowledge of "how" to do something. Backer et al. (2011) said it is "how specific cognitive skills are applied" (as cited in Sugiharto et al., 2018, p. 4). "Procedural knowledge often takes the form of a series of sequence of steps to be followed" (Anderson et al., 2001, p. 52), and is usually gained through practical experience (Elvira et al., 2017). It is also known as practical/experiential knowledge (Tynjälä, 2008).

Procedural knowledge is important because as we apply concepts using the mechanisms, methods, and procedures to solve problems, we gain practical experience (Heiberg Engel, 2008) and thus increase in confidence (Sugiharto et al., 2018). Additionally, effective procedural performance is based on how well one's conceptual knowledge is organized and how much conceptual knowledge one has (Bjorklund & Eloranta, 2008; Vasyukova, 2012). Tynjälä (2008) described the relationship between conceptual and procedural knowledge by explaining that conceptual knowledge transforms into procedural knowledge, and that procedural knowledge explicates conceptual knowledge. In other words, procedures equate to applied concepts, and once they are applied, they help the learner understand the concepts better.

Continuing the aforementioned examples, an architect may know what to look for in a high-quality design because he/she may have experienced the process of creating a design before. Likewise, a doctor may be better suited to examine an x-ray after having already gone through the process of examining x-rays before. These processes of designing architectural models and examining x-rays show the interplay and mutual reinforcement between the acquisition of concepts and procedures.

However, the concepts they understand and the processes they know how to perform may not be the complete explanation for proficient problem-solving. While many real-world problems may be solved with conceptual and procedural knowledge, many still come with their nuances that uniquely distinguish them from the rest. These nuanced real-world problems require more than knowledge of concepts and procedures to solve them.

**Conditional knowledge.** It is important to learn "what" and "how" to do something, but where expertise truly manifests itself to others is knowing "when" and "why" to do things in very specific situations (Amolloh, Lilian, & Wanjiru, 2018; Lorch, Lorch, & Klusewitz, 1993; Paris, Lipson, & Wixson, 1983). Conditional knowledge is recognizing the conditions under which you should employ your conceptual and procedural knowledge; it is knowing when to perform certain tasks and use specific skills (Oluwatayo, Ezema, & Opoko, 2017; Vasyukova, 2012). When one uses their conditional knowledge, they regulate and direct their conceptual and procedural knowledge. Amolloh et al. (2018) expounded on this by writing that conditional knowledge employs critical thinking and problem solving at a higher level, and that it can even increase confidence in one's ability.

For example, simply knowing how to draw various types of architectural designs does not qualify one as a skilled architect; one must also know the conditions under which to draw a specifically, efficient design based on the conditions on the ground. Similarly, knowing how to perform a plethora of medical procedures does not qualify one as a skilled doctor; one must also know when and why to perform them based on a combination of a multitude of symptoms. Understanding the conditions of a problem or situation are crucial in order to effectively apply conceptual and procedural knowledge.

One can use their conditional knowledge to manipulate their conceptual knowledge and their procedural knowledge to execute an effective solution to a specific problem (Turns & Van Meter, 2011). Conditional knowledge is necessary to solve problems efficiently, because it allows one to select the most appropriate solution out of multiple viable options, based on the unique characteristics of the problem (Sugiharto et al., 2018). Additionally, researchers van de Kamp, Admiraal, and Rijlaarsdam (2016) even found that explicitly teaching conditional knowledge to high school art students allowed them to brainstorm more easily and come up with more original ideas. Therefore, conditional knowledge seems to be a higher form of knowledge that allows you to use your conceptual and procedural knowledge in order to make original connections between the conditions of unique problems and potential solutions.

**Expertise is Knowledge**

Many instructional settings may be viewed through the lens of expertise development. Corporate, educational, and informal instruction are increasingly being viewed through the lens of expertise development (Barreiros & Abreu, 2017; Ellis & Smith, 2017; Elvira et al., 2017; Howard, 2012; Le Mire, 2016; Newell, Wu, Leingpibul, & Jiang, 2016). This section describes how expertise can be defined in terms of knowledge.

Expertise may be defined as having a large amount of knowledge within a discipline, and using that knowledge to adapt to and solve novel problems (Elvira et al., 2017; Ivarsson, 2017; Johnson, 2005; Oluwatayo et al., 2017; van de Wiel, 2017). Bjorklund and Eloranta (2008) and Cross (2003) realized that some experts may have a limited amount of knowledge but that it is more organized than others (as cited in Oluwatayo et al., 2017). Conversely, the more knowledge experts obtain and organize, the more adaptive they may become in solving problems that have not been encountered before (Vasyukova, 2012).

It should be noted that experts may be defined as two ways, routine experts and adaptive experts (Hatano & Inagaki, 1984; Hatano & Oura, 2003). Routine experts are people who recognize features in a problem and identify what course of action is needed to solve the problem. Adaptive experts are people who can find solutions to unforeseen or new circumstances. Adaptive experts have practiced solving multiple problems within a context that has inherent variety, and which requires the expert to understand how to work with the objects and constraints available in each given situation (Hatano & Inagaki, 1984; Hatano & Oura, 2003). Therefore, routine experts recognize previously seen features of a problem to find a solution, and adaptive experts assess new features they have never encountered before but still find a solution.

Bransford et al. (2000) noted that one thing that sets experts apart is that their knowledge is conditionalized. Experts are skilled at decision-making under novel situations for a variety of reasons (Elvira et al., 2017; Ivarsson, 2017; Johnson, 2005; Oluwatayo et al., 2017; van de Wiel, 2017). Not only do they have knowledge of facts and procedures, but they understand the conditions under which to apply that knowledge (Amolloh et al., 2018; Elvira et al., 2017; Lorch et al., 1993). Thus, the question of "how" experts use their knowledge may be as equally important, or more important, than the question of "how much" experts know. Furthermore, it seems that conditional knowledge could then be considered an essential aspect of expertise (Amolloh et al., 2018; Elvira et al., 2017; Lorch et al., 1993), because conditional knowledge informs how knowledge is used in a variety of circumstances and scenarios.

Barrotta and Montuschi (2018) wrote on the topic of experts using conditional knowledge. They said that some people only use "general knowledge" (knowledge of concepts and facts) to solve problems, expecting that theories can be universally applied to all problems in order to solve them. However, they explained that "local knowledge" (knowledge of the specific conditions of a specific problem) is a necessity in order to supplement the broad, conceptual understanding of a discipline and find solutions, because concepts do not have the capacity to fully explain every problem (Barrotta & Montuschi, 2018, p. 387).

Novice students may not be able to control their conceptual and procedural knowledge in a way that allows them to solve problems effectively. Hestenes, Wells, and Swackhamer (1992) discovered that physics students can perform calculations better than they can answer conceptual questions on the material. Their conclusion was that students relied more on the rote procedures required to solve problems than on their actual understanding of why they performed those procedures in order to solve those problems. This shows that there may be a need for developing conditional knowledge in order to help students make connections between procedures and the concepts that inform their use.

In summary, expertise can be viewed as mastery of knowledge (in this case, knowledge refers to both understanding concepts and having the skills to act on that conceptual understanding). Specifically, experts have learned to synchronize their conceptual, procedural, and conditional knowledge, that is, the ability to perform optimally to solve a unique problem (Elvira et al., 2017; Ivarsson, 2017; Johnson, 2005; Oluwatayo et al., 2017; van de Wiel, 2017). Considering that conditional knowledge seems to be a salient feature of expertise, if we can teach conditional knowledge more explicitly in our instructional settings, then we may accelerate a novice's process to becoming an expert.

**How to Develop conditional Knowledge**

How is conditional knowledge learned and taught? In this section we review the literature about the nature of developing conditional knowledge, that is, how it is transmitted from one person to another. This information may be of particular help for professors in developing expertise in novice students.

Elvira et al. (2017) identified ten principles in a meta-analysis for teaching expertise, and three of those relate directly to teaching conditional knowledge. These three principles were organized into Tynjälä's (2008) domain for knowledge, reflecting on both procedural and conceptual knowledge by using self-regulative knowledge. They refer to conditional knowledge as self-regulative knowledge, but the meanings are the same.

One of those principles is to support students in strengthening their problem-solving strategies (Elvira et al., 2017). Scaffolding is one way to do this (Evans, 2008). Scaffolding may involve having the learner watch and mirror the teacher's example. It may also help students build their confidence, as is the case with apprenticeship (Collins, Brown, & Holum, 1991). Guided practice or coaching is another way to support students. The teacher may be at the learner's side as the learner practices solving problems. Yuan, Wang, Kushniruk, and Peng (2017) suggested that teachers can do this using visual, conceptual maps representing expert thinking so that learners can mimic how experts solve problems. These are a couple of ways to strengthen learners' problem-solving strategies.

The second principle is to evoke reflection so that implicit processes become explicit (Elvira et al., 2017). This can be applied by having learners compare their solutions to expert solutions (Hagge, Amin-Naseri, Gilbert, et al., 2015; Hagge, Amin-Naseri, Jackman, et al., 2017; Yuan et al., 2017). Additionally, this can be carried out by providing immediate (King, 2009) and formative (Hallam, 2010) feedback whenever the learner needs it. Having learners reflect on their own thought process and compare it to those of experts can help learners organize and solidify an effective mental map for solving problems (Greca & Moreira, 2000). Teachers should help learners actively evaluate *how* they think, instead of letting learners passively think through their erroneous thought processes.

The last principle is to facilitate the development of metacognitive knowledge and skills (Elvira et al., 2017). Sugiharto et al. (2018) stated that the "regulation of cognition comprises five skills: planning, information management strategy, comprehension monitoring, debugging strategy, and evaluation" (p. 3). In order to help learners gain these skills, Joseph (2006) suggested that teachers explicitly tell learners the metacognitive skills they will need, model their thinking for learners, and promote learners to ask many questions. Similarly, Alexander (2003) suggested that learners must be taught explicit strategies on how to think about problems in order to solve them, and to pose new questions that expand the current domain of knowledge. If teachers tell learners *how* to think, in addition to *what* to think, then learners may improve upon their conditional knowledge.

To restate, the principles enumerated may help foster conditional knowledge: supporting students in strengthening their problem-solving strategies, evoking reflection, and facilitating the development of metacognitive knowledge and skills. As these principles are implemented, learners may gain conditional knowledge that will help them understand when and under what conditions they should apply their conceptual and procedural knowledge. This now begs the question, what impedes experts from teaching their conditional knowledge?

**Experts Struggle Teaching Conditional Knowledge**

One of the ironies of teaching is how experts, individuals who know a great deal about a subject, struggle conveying their knowledge to novices, those who know very little about a subject (Bransford et al., 2000). Some experts know a discipline so well that their content knowledge overshadows their pedagogical ability to effectively teach that topic to a novice (Nathan & Petrosino, 2003). Put simply, they may be experts, but still not know how to communicate their knowledge to someone else. Regarding this difficulty, Eric Mazur of Harvard University instituted peer instruction because he realized that a "student who understands [a concept] is sometimes better at explaining it to others than I am" (Travis, 1994, p. 893).

Professor Mazur recognized his struggle to teach his expert thinking to his novice students (Mazur, 1997). Yuan et al. (2017) summarized this difficulty in the following way:

> Solving a real-world problem often involves a sophisticated process of understanding the problem, linking abstract knowledge to problem information, and applying relevant methods and strategies to solve the problem. Learning in such contexts can generate a heavy cognitive load for learners (Kirschner, Sweller, & Clark, 2006) that instructors or experts often underestimate, as for them many of the requisite processes have become largely automatic or subconscious with experience. (p. 233).

That automation that Yuan et al. (2017) talked about includes all the types of knowledge that constitute expertise, including conditional knowledge. Almost without thinking, experts use their conditional knowledge to make the decisions that make the most sense to them. This automation makes it difficult for experts to relate to novices because experts may have forgotten how it feels to not possess such automatic and subconscious thinking processes, especially as time passes (Mazur, 1997; Travis, 1994). Therefore, the mentally automated use of conditional knowledge may make it difficult for experts to even teach because it has become implicit and tacit.

Another impediment may be that experts simply do not know how to explicitly teach conditional knowledge. Meyer (2018) interviewed 16 secondary school teachers implementing a new teaching strategy that includes the elements of conditional knowledge (such as making decisions under unfamiliar conditions, and metacognitively evaluating your thought process), and found that they had difficulty doing so because they simply did not know how. More specifically, “teachers believe they provide their students with opportunities to practice clear procedural, and observable, steps in making a decision, but are not particularly strong in supporting the students thinking about their internal intellectual processes" (p. 8). Additionally, in a review of the educational research of learning, Garner (1990) mentioned that the main thing that may be preventing learners from using their metacognitive skills (which is needed in conditional knowledge), is that they do not recognize the importance of the problem setting, or the conditions and constraints of the problem. Therefore, teachers may not know how to teach conditional knowledge because they do not emphasize the importance of the problem setting, or the conditions of the problem.

**Teaching Conditional Knowledge Internationally**

Other unknowns in teaching conditional knowledge are how to do so across multicultural boundaries, if it is even different at all. Conditional knowledge is recognized across cultures as an important aspect of learning. In Italy, the researchers Barrotta and Montuschi (2018) emphasized the importance of conditional knowledge by explaining how local knowledge, in addition to general knowledge, is necessary in order to understand and solve local conditions of unique, real-world problems. Additionally, Sugiharto et al. (2018) studied pre-service biology teachers in Indonesia and recognized that conditional knowledge was the most important aspect of their cognition.

University professors in financially strapped colleges are struggling to improve their pedagogy (Flores Jiménez, Fernández Arata, Juárez García, Merino Soto, & Guimet Castro, 2015) due to limited resources. These international educational institutions are particularly in need of support on how to teach conditional knowledge, because it could be argued that these are the countries which are most in need of this knowledge and training, due to the obstacles these students encounter when seeking meaningful employment in a competitive global market. What these countries need are strategies for teaching conditional knowledge, or transferring expertise, that can be used in varied settings and contexts.

Teaching conditional knowledge is a struggle internationally. Amolloh et al. (2018) recognized that, in Kenya, “inadequate preparation in educational courses coupled with improper supervision and feedback impede effective professional development in most universities” (p. 125). So, these researchers provided professional development based on the experiential learning theory by Kolb (1984) that included experiential learning and a focus on conditional knowledge. The participants were 68 teacher trainees (65% of whom were male) who come from 17 different counties in Kenya. After surveying them, 78% of the trainees reported feeling “very well” prepared to teach, and 21% reported feeling “well” prepared. These findings not only suggest that Kenyan teacher trainees significantly benefited from developing conditional knowledge, but also that they may not have learned these principles without help.

**Summary of the Problem**

In summary, expert teachers may have difficulty teaching conditional knowledge to their student novices because of the decreasing capacity experts have over time to empathize with novices. Additionally, conditional knowledge seems to be valued internationally, and highly needed in developing countries.  Considering these struggles, and the lack of tools that help experts teach conditional knowledge, a pedagogy called decision-based learning (DBL) (Plummer et al., 2017) was developed.

**Decision-Based Learning to Teach Conditional Knowledge**

Plummer et al. (2017) claim that a newly developed pedagogy called decision-based learning is a universal instructional method that can be used to teach various disciplines (from STEM to arts courses) and help overcome challenges in developing conditional knowledge. DBL helps novices accelerate their progress to becoming experts. DBL provides extensive scaffolding that gradually fades, numerous examples, and regulated feedback. DBL has helped teachers better foster conditional knowledge in learners (Plummer et al., 2017).

Before I explain DBL more in depth, I will review comparable pedagogies. There are various pedagogies that focus on using decisions to guide the learning process, and some even used the term "decision-based learning" as well to refer to their pedagogy. All are similar but have essential differences. After reviewing them, I will contrast them with how Plummer et al. (2017) use decision-making in their pedagogy.

**Previous Approaches to Decision-Making in Learning**

Meyer (2018) focused on decision-making as she and others embedded Challenge-based Learning (CBL) in teaching the Engineering Design Process (EDP) for a faculty development training. She surveyed 16 middle and high school teachers out of 100 before they thought about the focus on decision-making in the training. She found that the "teachers believed they did not make clear to students why they were making the decisions and/or clarifying the potential impact of a decision" (p. 8). The application of the decision-making aspect of this model is not described in detail, but this article makes evident that either efficient pedagogical training or an effective pedagogical tool may be needed to help teachers implement decision-based learning.

Hagge Amin-Naseri, Gilbert, et al. (2015) and Hagge, Amin-Naseri, Jackman, et al. (2017) had 373 undergraduate students do a thermodynamics activity in a computerized tutoring system that was using decision-based learning. Students took a pre-test on their knowledge of thermodynamic concepts, and then immediately had to solve a thermodynamics problem, which consisted of multiple steps that required them to draw thermodynamic diagrams. The computerized tutoring system would then decide whether or not it needed to tutor the student, depending on the diagrams that the students submitted. Students then took a post-test to measure any gains in learning. The immediateness of the pre- and post-tests were able to control for many covariates, and they found that students had a highly significant gain in understanding ($p<0.0001$, $d>0.8$). The researchers recognized the benefits of applying decision-based strategies into the "conditional knowledge" of the software. However, the decisions were made by the computer system, not the students themselves.

Law, Pittman, and Miller (2014) were recognized for developing a pedagogical strategy called decision-based learning for teaching how to diagnose and treat rheumatic diseases. Law et al. presented many difficult, fictional cases that their students had to work through in groups, with constraints like patient history and a budget. Students developed critical thinking skills in trying to diagnose their fictitious patients, and they also developed more confidence in their skills. The students from this treatment group took a survey at the end of the course and gave significantly more positive feedback of the decision-based pedagogy than the students from the control group ($p<0.01$). About 67% of the treatment students rated their class experience at "10" on a 10-point Likert scale, while only 35% of the control group rated their class experience a "10." However, this pedagogy, like the thermodynamics one, was discipline specific.

**A New Approach to Decision-Making in Learning**

The challenges identified from the aforementioned versions of decision-based learning are teacher confidence in pedagogical skills, having students go through the decision-making process themselves, and expanding the domain of the model. The version of decision-based learning that Plummer et al. (2017) created attempts to address each of those challenges and more. Implementing this version of DBL may alleviate the teacher's pedagogical efforts while allowing students to develop critical thinking skills about the information being taught.

Additionally, students from multiple disciplines can undergo intensive practice of their decision-making skills with numerous problems.

Since technology is increasingly resourceful in the field of education, DBL has a software that accompanies it. The software seems to help facilitate the learning process in a DBL classroom setting (Plummer et al., 2017). Anticipating the benefits of technology as a resource for teaching expertise, Bol and Garner (2011) wrote:

> For example, if learning materials were to be presented through the medium of an electronic learning platform, and if that platform could support flexible problem solving behaviors by presenting a sequence of steps through which students can navigate in order to consider more and less likely solutions to a problem, then students may be able to interact more effectively and strategically with the information even while they are relative novices in the subject area. (p. 116)

The DBL software allows teachers to create what are called "decision models." Decision models are like decision trees where a student analyzes a question, or "decision point," selects an answer from the available branching options, and is taken to the consequent decision point until he/she reaches the end, and arrives at the chosen course of action to take (see Figure 1).

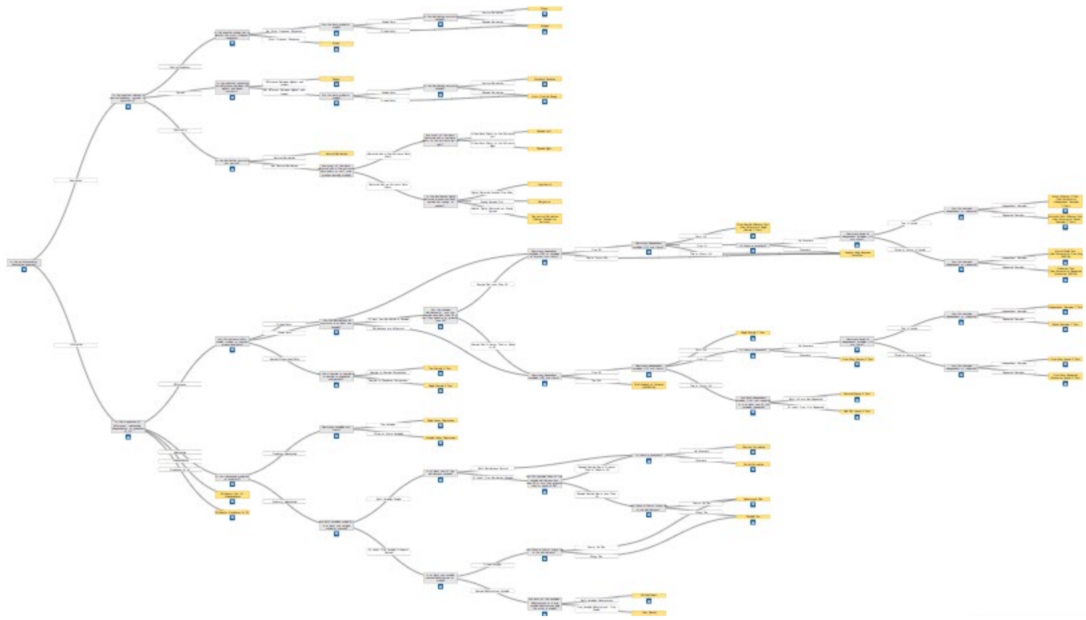

*Figure 1.* DBL model. This model shows various decision points, options, and final courses of action.

I will now begin to provide summarized instructions on how to effectuate the DBL pedagogy. Students are first presented with a “concrete example/problem” to take through the decision model. If the students do not know the correct option for a specific decision point, then they can click on a button below that decision point that says, “How do I decide?” By clicking that button, the software will take the student to a “learning module” that the teacher designed before-hand to provide “just enough, just in time” instruction for how to make that one decision (see Figure 2).

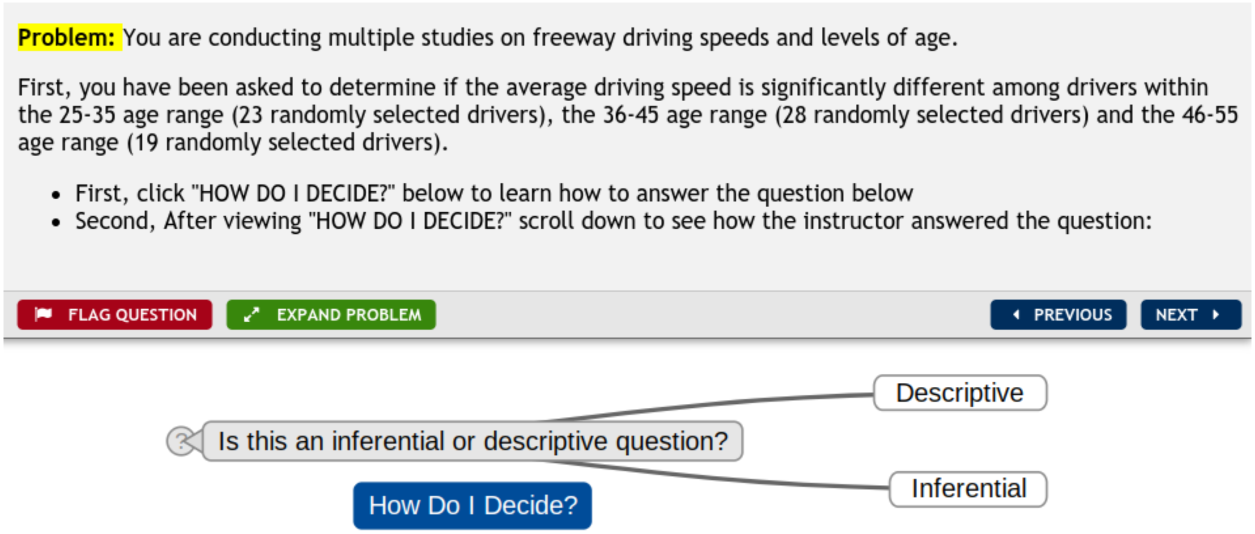


*Figure 2.* Concrete problem. A concrete problem is presented, and the student can click on ¨How Do I Decide?¨ to receive instruction on how to make this initial decision.

Once the student gains just enough instruction to know what option is best to select for the specific concrete problem being solved, then the student makes that decision and moves to the next decision point. This interactive problem-solving occurs with dozens and hundreds of problems that the teacher or teacher aids can create, and it provides students with a plethora of exposure to different, nuanced problem settings.

When teachers or experts physically carry out the pedagogy in an instructional setting, DBL requires that they start by explaining the purpose of the course to students, so that students start thinking about their previous knowledge on the subject. Then the teacher explains the purpose of DBL, in order to mentally prepare students for this new pedagogy (especially if this is the first time they are experiencing it). Contrary to traditional, deductive pedagogy, the instructor then presents a concrete example/problem first, before the instruction. Typically, the students will not know how to solve it, so this requires the students to look for key features of the problem that indicates what course of action to take. This way, learning takes place as fulfilling a need instead of passively transmitting information. Therefore, students learn within the context of solving a concrete, real-world problem, thus fostering conditional knowledge.

At the first decision point, where the students do not know what to choose, the teacher clicks the "How Do I Decide?" button in the software in order to access the teacher's previously created instruction. The teacher provides "just enough, just in time" instruction, and ensures that the students have learned how to make the decision by providing a few separate practice problems where multiple, similar questions are asked. Students are called on to respond to these practice problems and are then asked to defend their answers. The students are given the opportunity to debate what decision they should make as a class and may even correct each others' thinking. Once the students go through the practice problems, the instructor takes them back to the original concrete example to officially answer the first decision point. The instructor follows this pattern across multiple decision points until the students complete the learning outcome for that day.

For homework, the students can then go through a plethora of problems on their own. Homework using DBL software is where the pedagogy can help most, because that is where the learner can gain confidence and correct any errors in their thinking (Plummer et al., 2017). The DBL software provides feedback features that help the learner identify which decision points they need to practice more. Teachers can adjust the feedback settings at different levels of immediateness. The software also keeps track of the quantity of problems students have taken through each part of the model and if they chose correctly or not. So, teachers can not only compare which concepts have been practiced more than others, but also which decisions have been chosen correctly more often than others. The teacher can then review each students' model in order to pinpoint and identify which concepts each student is doing well on, and which ones they need to practice more. Therefore, the software records and indicates to the teacher which decision points each student performs well on, and which ones they struggle with.

**Previous DBL Implementations**

Plummer et al. (2017) performed a small pilot study on the effectiveness of this new DBL approach. They distributed surveys to 112 students who came from one statistics course, and two differential equations courses. The results showed that most of the students benefited from the DBL experience. Their academic performance improved, and they reported being able to learn the material with more ease. However, there were some difficulties with following along the decision model. These usability issues were traced to implementation issues. This suggested that better guidance and/or training will be needed for those who are implementing DBL in their learning spaces.

Also, Sansom, Suh, and Plummer (2019) implemented DBL in a chemistry class in order to see how it might affect scores on a heat and enthalpy test. The same exam was distributed to two separate cohorts of students. One cohort received the professor's original instruction ($N$=222), and the other cohort received the professor's DBL instruction ($N$=199). The professor provided the experimental DBL instruction for two class sessions, and then recorded the student activity on the DBL software to see how they performed on their homework. There were 129 students who attended both DBL class sessions, while the other 70 students attended one or neither. The students who used the software for five problems or ten problems had higher test scores on the heat and enthalpy test than the students who did not receive the DBL instruction. The control group got a test score of 4.5 and the students who did five and ten DBL problems had mean differences of +0.626 ($p$=0.002) and +0.577 ($p$=0.018), respectively. This implementation suggested that DBL helped students increase their academic performance.

## Conclusion

In summary, professors could benefit from educational technology that improves their efforts to instill expertise in their novice students and prepare them for the workforce. The extensive research on knowledge and expertise-development informed the creation of DBL and seems to sustain its theoretical foundation. The way that the DBL software exposes learners to a variety of situations in which they apply their knowledge allows learners to develop expertise the way Hutton and Klein (1999) described it, which is by making decisions “based on situation awareness, on the recognition of situations as typical or anomalous” (p. 33).

However, according to the past implementations of DBL, there may need to be some improvements to the usability of the software, as well as to the training for how teachers and experts can implement DBL. Updates in the software have been made, but not much has been done to improve the training. In order to understand what training improvements may be necessary, I performed a case-study with the purpose to examine the lived experience of someone implementing DBL for the first time. This will hopefully reveal the key pain points one experiences in this process, which will thus inform how exactly to improve upon it.

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APPENDIX B

**Instruments**

Professor Survey

1. What is Decision-based Learning?
2. What were the BENEFITS of implementing Decision-based Learning?
3. What were the CHALLENGES of implementing Decision-based Learning?

Interview Protocol for Professors who implemented DBL

1. What does DBL look like in your classroom? (what do you do, how do you do it (with software or not), etc.)
2. How often do you use DBL in your class? (can answer in days, minutes, etc.).
3. How have students responded to you implementing DBL in your classroom?
4. What do you think are the strengths of DBL?
5. What challenges have you encountered?
6. What do you think is your role as a teacher in a DBL class?
7. What do you think is the students' role in a DBL class?
8. According to our understanding, each university professor teaches in their own way, and it’s not common to collaborate among colleagues about each others’ pedagogies. Has this influenced at all in your implementation of DBL?

Survey given to Jane’s students

1. What class are you enrolled in?
2. Who was your professor (first and last name)?

3. In which semester did you take the class?
4. Which lesson of the course used DBL? Ask your professor if you don't know.
5. In your opinion, what's the difference between DBL and other teaching methods you're used to in this class?
6. What were the benefits of using DBL in this course?
7. What were the challenges of using DBL in this course?
8. On a scale of 1 to 5 how effective was the DBL method?
    a. Not effective 1 2 3 4 5 Very Effective
9. On a scale of 1 to 5, how did DBL help you with retention of the material?
    a. It Doesn't Help with Retention 1 2 3 4 5 Helps a lot with Retention
10. How much did DBL prepare you to resolve problems by yourself in this field?
    a. Nothing 1 2 3 4 5 A lot
11. How did DBL help you resolve problems by yourself in this field?

Interview Protocol for Jane's Students

1. Please explain your understanding of DBL.
2. What's the difference between DBL and other pedagogies, like Problem-based Learning?
3. In your opinion, what are the strengths of using DBL?
    a. What do you like about DBL?
4. In your opinion, what are the weaknesses of using DBL?
    a. What was challenging about implementing DBL?
5. What do you think is the teacher's role in a DBL class?
6. What do you think is the student's role in a DBL class?

7. How did your professor introduce DBL to your class?
    a. How excited was he/she about this new teaching method?
8. What were your expectations of this new teaching method when it was introduced to your class?
9. What did you hear or did you discuss with your classmates about DBL?
    a. Positive things?
    b. Challenges?
10. One challenge that we've noticed in DBL implementation is using the software. Did you have any challenges using the DBL software? If so, please explain.
11. When was the last time you tried to do something different about the way you learned or studied?
    a. If yes, did you feel any opposition from students, family, friends, professors, etc.?
    b. If not, why not?

Rubric - Implementation Fidelity of Videos

1. Present the purpose of the course
2. Present how DBL will help accomplish the learning objective
3. Present a concrete example of a problem to be solved or something to be evaluated
4. Present the first decision point with its options
5. Provide just-enough-just-in-time instruction
6. Provide at least two practice examples
7. Return to the original concrete example to choose an option
8. Repeat until you reach the end of the model

APPENDIX C

**IRB Approval**

To: Richard West, Ph.D.
Department: IP&T
College: EDUC
From: Sandee Aina, IRB Administrator, MPA
Date: September 20, 2018
IRB#: A 18-392
Subject: Effectiveness of Decision-Based Learning Strategies

Thank you for your recent correspondence concerning your protocol referenced in the subject heading. Brigham Young University's Institutional policy requires review of all research. I appreciate your willingness to comply with this policy.

According to the Code of Federal Regulations 45.46.102 (d), research is defined as:

> a systematic investigation, including research development, testing and evaluation, designed to develop or contribute to generalizable knowledge.

You have communicated that the study is to provide an evaluation of the implementation of instructional methods to a local group of educators in Peru. The resulting data will be specific to this group and cannot be used outside of this purpose—this project is not under the jurisdiction of the IRB.

The determination is that the activity does not meet the regulatory definition of human subjects research.

Please remove any references to the IRB on consent or cover letter documents. Any publication/presentations should not refer to this evaluation as human subject research or that it can be used for generalizable purposes. If there will be future plans to expand the evaluation to include research, you would submit an application to the IRB at that time.

Respectfully,
Sandee M.P. Aina, MPA
Institutional Review Board for Human Subjects, Administrator
Of ice of Research & Creative Activities
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