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## Effects of success v failure cases on learner-learner interaction

Andrew A. Tawfik<sup>a,\*</sup>, Philippe J. Giabbanelli<sup>b</sup>, Maureen Hogan<sup>c</sup>, Fortunata Msilu<sup>c</sup>, Anila Gill<sup>c</sup>, Cindy S. York<sup>d</sup>

<sup>a</sup> Instructional Design & Technology, University of Memphis, 3798 Walker Ave, Ball Hall - Office 421D, Memphis, TN 38111, United States

<sup>b</sup> Northern Illinois University, Computer Science, Office PM 460, 1425 W Lincoln Hwy, DeKalb, IL 60115, United States

<sup>c</sup> Northern Illinois University, 1425 W Lincoln Hwy, Gabel Hall (Office 208), DeKalb, IL 60115, United States

<sup>d</sup> Northern Illinois University, 1425 W Lincoln Hwy, Gabel Hall (Office 101E), DeKalb, IL 60115, United States



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### ABSTRACT

Studies have found that students struggle to challenge their peers and engage in co-construction of knowledge when in asynchronous problem-based learning (PBL) contexts. In other settings, case libraries have been shown to support problem solving competencies, such as argumentation and problem representation. However, research has yet to study how the design and types of cases impact learner-learner interaction. To accommodate that gap, this study used content analysis and sequential analysis to ascertain how learner interaction differed when participants had access to success- and failure-based case libraries. Results found the failure-based condition had higher overall number of postings and differed in terms of the number of elicitations and planning (meta) interactions. Finally, results of the sequential analysis indicated participants in the success-based condition were more likely to begin planning their final assignment earlier, while the failure condition was more likely to continue engaged in collaborative problem-solving with their peers. Given these differences, the findings suggest failure-based cases may serve as a catalyst for learner-learner interaction when compared with success-based cases. Implications for practice, case-based reasoning, and failure-driven memory theory are discussed.

### 1. Introduction

Research finds that practitioners are often required to solve complex, ill-structured problems in a variety of domains (Gartmeier, Bauer, Gruber, & Heid, 2010; Hara & Schwen, 2006). Contextualized examples include physicians prescribing proper medicine to avoid post-surgery infection, engineers selecting optimal materials during the construction of a bridge, and sales personnel growing a business amidst market challenges. Because these problems possess multiple possible solutions and perspectives, practitioners must interact with their peers to generate viable solutions given available evidence and contextual constraints (Hmelo-Silver, 2004; Jonassen, 1997, 2011b). Specifically, individuals and their peers proffer ideas, ask questions, and engage in consensus building during collaborative problem solving. Moreover, communities of practice frequently leverage prior experience during problem solving (Tawfik & Kolodner, 2016; Hara & Schwen, 2006; Kolodner, Owensby, & Guzdial, 2004). In many cases, individuals rely on causal reasoning and requisite evidence of past experiences to justify a solution for a given problem.

Given the research on how practitioners solve complex problems, theorists have argued learners should be taught in a similar manner (Herrington, Reeves, & Oliver, 2014; Jonassen, 1997; Kolodner et al., 2004). Similar to communities of practice, learners in

\* Corresponding author.

E-mail addresses: [aatawfik@gmail.com](mailto:aatawfik@gmail.com) (A.A. Tawfik), [pgiabbanelli@niu.edu](mailto:pgiabbanelli@niu.edu) (P.J. Giabbanelli), [mhogan5@niu.edu](mailto:mhogan5@niu.edu) (M. Hogan), [fmsilu1@niu.edu](mailto:fmsilu1@niu.edu) (F. Msilu), [agill5@niu.edu](mailto:agill5@niu.edu) (A. Gill), [cindy.york@niu.edu](mailto:cindy.york@niu.edu) (C.S. York).

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problem-based learning (PBL) are tasked with solving problems that are representative of the duties practitioners often encounter. Reciprocal discourse between group members, also known as learner-learner interaction, plays an important part in PBL (Donnelly, 2010; Moore, 1989). Similar to practitioners, learners in PBL must interact with their peers to externalize ideas, ask questions, and negotiate meanings in pursuit of a solution (Hull & Saxon, 2009; Jeong & Hmelo-Silver, 2016; Lajoie et al., 2014). However, research indicates that novices employ domain-dependent strategies, such as means-end analysis, and fail to challenge the assertions of their peers during problem solving (Oh & Jonassen, 2007; Tawfik, Sánchez, & Saporova, 2014). This reticence to challenge peers is even more pronounced when learners collaborate in online asynchronous PBL contexts (Ertmer & Koehler, 2014). To address this problem, scaffolds such as question prompts (Vogel et al., 2016; Weinberger, Ertl, Fischer, & Mandl, 2005; Kauffman, Ge, Xie, & Chen, 2008) and wikis (Brooks & Jeong, 2006; Ioannou, Brown, & Artino, 2015) have been embedded in online learning environments to stimulate learner inquiry in the problem space and serve as a catalyst for deeper learner-learner interaction required for PBL.

Learning systems have also started embedding “cases as previous experience” (Jonassen, 2011a, p. 194) as scaffolds. Because learners often struggle to synthesize information and engage in causal reasoning, cases allow the learner to observe how practitioners solved similar problems and apply lessons learned toward the extant problem (Dabbagh & Doss, 2013). In contrast to other forms of scaffolding, PBL groups can use cases to generate ideas, ask questions, and negotiate how the previous experience depicted in the solution can be transferred to the new problem. Some have further argued scaffolds go beyond other forms of support by modeling behavior and depicting causal reasoning in narrative form (Tawfik & Kolodner, 2016; Gartmeier et al., 2015; Hoogerheide, Loyens, & van Gog, 2015).

While research has begun to validate the use of cases as a viable scaffolding strategy, qualitative reflections of case libraries comprise much of the evidence (Bennett, 2010; Boshuizen, Wiel, & Schmidt, 2012; Kim & Hannafin, 2009). It is thus less clear how learners employ scaffolds to enhance the learner-learner interaction that is critical for PBL. Moreover, research has yet to explore how different types of experiences depicted in a case, such as success or failure, might generate different types of learner-learner interactions within PBL groups. Based on this gap, we first examine relevant research associated with PBL and learner-learner interaction in online asynchronous learning contexts. We then discuss the theoretical merits of case-based reasoning (CBR) and failure-driven memory. Finally, we present results on the use of success- and failure-based cases on interaction in terms of content analysis and sequential analysis.

## 2. Literature review

### 2.1. Problem-based learning and online learning

In many educational settings, instruction is often administered with didactic and lecture-based approaches. Learners in those instructional settings memorize important information conveyed by the teacher or assigned in the learning materials (Herrington et al., 2014). The transfer of knowledge and interaction often occurs through exchanges between the instructor and student, while also often devoid of context (Ng, Bridges, Law, & Whitehill, 2014). Moreover, learners in traditional classroom contexts are often assessed using single answer, well-structured problems. Despite being efficient models of teaching, critics have suggested didactic-based approaches fail to represent the complexity required to solve complex, domain-specific problems (Barrows & Tamblyn, 1980; Hmelo-Silver, 2004; Jonassen & Hung, 2008).

Given how practitioners solve problems, theorists argued instruction should emphasize the skills needed to solve ill-structured problems (Hmelo-Silver, 2004; Hung, 2011). Thus, PBL is an instructional strategy used to overcome the pedagogical limitations of didactic teaching by allowing novice learners to solve representative domain problems with peers (Barrows & Tamblyn, 1980; Hmelo-Silver, 2004). An important part of the ill-structured problem-solving process required in PBL includes how peers collaborate (Lu, Lajoie, & Wiseman, 2010; Moore, 1989). Specifically, PBL interactions require learners to proffer ideas for solving the problem, identify disagreements, ask relevant questions, and come to consensus as they monitor their own understanding (Hmelo-Silver & Barrows, 2008; Jeong & Hmelo-Silver, 2016). Further, sociocultural theory posits that externalized knowledge becomes internalized over time as learners interact with each other (Vygotsky, 1978). This internalization of the learner-learner interaction results in developing cognitive skills, such as critical thinking, problem-solving, and creativity (Ioannou & Stylianou-Georgiou, 2012).

The contextualized nature of PBL aligns especially well with constructivist approaches to online learning (Tee & Lee, 2013) and the degree of interaction required in these contexts. Moore (1989) hypothesized three different, yet complementary, forms of interaction: learner-instructor, learner-content, and learner-learner. Learner-instructor interaction describes the discourse between the teacher and student. Alternatively, learner-content interaction emerges between the student and subject matter, with a particular emphasis on the materials (e.g., readings). Finally, learner-learner interaction entails the dialogical processes between peers. This dynamic process entails learners engaging with peers to share ideas, ask questions, and negotiate new knowledge (Storch, 2002; Weinberger et al., 2005; Hmelo-Silver & Barrows, 2008; Jeong & Hmelo-Silver, 2016). How peers interact with each other influences the degree to which they are able to learn and later internalize their discussions (Sato, 2017).

While Moore's (1989) original definitions were not specific to collaborations that happen online, they are particularly important in asynchronous learning contexts. In contrast to face-to-face learning environments that emphasize learner-instructor interaction, learners in online learning often collaborate using discussion boards to discuss the materials for a given week. In doing so, the dynamic shifts away from learner-instructor interaction towards learner-learner interaction. However, research finds that discussions are often topical and rarely result in sustained learner-learner interactions that engender critical thinking (Chiang & Fung, 2004; Richardson & Ice, 2010). Comparatively, PBL varies widely from the read/reflect/respond learner-learner interaction cycle often used in many online courses. When PBL is contrasted with other strategies used in online learning, research findings suggest that its

integration leads to improved online interactions in terms of critical thinking skills (Şendağ & Ferhan Odabaşı, 2009; Lu et al., 2010), externalization of ideas (Tee & Lee, 2013), social cohesion (Lajoie et al., 2014), self-efficacy (Brown, Lawless, & Boyer, 2013), and metacognition (Choi, Land, & Turgeon, 2005). Koh, Herring, and Hew (2010) thus contends that PBL groups “think deeper, conduct more research, and discuss more effectively which could improve their high level thinking skills” (p. 139).

While asynchronous online PBL has shown promise, research has also found significant challenges to meaningful learner-learner interactions. Some of these challenges include managing group dynamics and maintaining focused interactions to foster co-construction of knowledge (Eryilmaz, Pol, Ryan, Clark, & Mary, 2013; van der Pol, Admiraal, & Simons, 2006). In a review of the online PBL research, Oncu and Cakir (2011) concluded that, “it is very uncommon to see fruitful discourse among online groups working collaboratively” (p. 1099). In instances when online PBL learner-learner interactions have been explored, learners were reticent to interact in ways that challenge or disagree with their counterparts (Ertmer & Koehler, 2015; Oh & Jonassen, 2007). Similarly, learners fail to challenge or integrate the posts of their peers (Ertmer & Koehler, 2015; Hou, 2011). Collectively, research findings suggest that online PBL contexts often do not sustain the requisite learner-learner interaction needed to fully solve the problem.

To overcome the challenges of PBL in asynchronous discussion boards, some learning technologies have been employed to better scaffold learner-learner interaction (Ravitz & Blazeviski, 2014; Rienties et al., 2012). For instance, studies find wikis support co-construction of knowledge (Ioannou & Stylianou-Georgiou, 2012) and idea generation (Ardaiz-Villanueva, Nicuesa-Chacón, Brene- Artazcoz, Sanz de Acedo Lizarraga, & Sanz de Acedo Baquedano, 2011) in PBL when compared with traditional online discussion forum formats. Similarly, Lu et al. (2010) found the presence of an online whiteboard better supported interaction in terms of negotiation of meaning and consensus building. Alternatively, Williams van Rooij (2009) implemented an online learning system that redesigned the discussion forums to be more in line with project-management software (project management body of knowledge; PMBOK®). Although the artifacts examined found no differences between the PMBOK and control groups, content analysis indicated improved interaction in terms of facilitation of group understanding. Other approaches such as mobile technology (Lan, Tsai, Yang, & Hung, 2012) and social media (Lin, Hou, Wu, & Chang, 2014) have been shown to incite the peer interactions required of PBL. Based on the research, results suggest technological scaffolds serve as an important aspect of learner-learner interaction in online PBL contexts.

## 2.2. Case-based reasoning

In addition to peer interaction, an inherent challenge to online PBL is that students’ lack of previous experience required to solve complex, ill-structured problems (Kolodner et al., 2004; Schank, 1999; Tawfik & Kolodner, 2016). As a result of this gap, Hoffman and Richie suggested (1997) that PBL is difficult to implement because students struggle to generate solutions while simultaneously being responsible for knowledge acquisition. Similarly, critics have argued that encountering ill-structured problems in PBL precludes meaningful learning (Kirschner, Sweller, & Clark, 2006); that is, learning concepts and solving contextualized problems is beyond the cognitive load of learners. Implicit within the argument is that the complexity stems from the lack of previous experience needed to inform a solution when presented with a PBL problem (Kolodner et al., 2004; Tawfik & Kolodner, 2016).

Case-based reasoning (CBR) researchers have also argued that prior experience is key to understanding and solving new problems (Schank, 1999). According to CBR, as an individual encounters a new situation, they first try to solve it using a similar case (retrieval). If the case is seen as relevant based on their similarity assessment (Xiong, 2011), they will apply the lessons learned to resolve the problem (reuse). If no relevant case is found within memory, the individual will revise his/her understanding, and the experience will be stored as a new case within memory. Over time, experts generate increasingly comprehensive case libraries that inform solutions to domain-specific problems. However, if individuals lack relevant experience, they will struggle to solve new problems because they do not have the case library in memory that informs a solution (Bennett, 2010; Jonassen & Hernandez-Serrano, 2002).

CBR theory has important implications for PBL and learner-learner interaction. CBR theorists have suggested providing a representative set of cases (case library learning environments) to contextualize relevant concepts needed to solve a problem as one way to scaffold the experience gap (Jonassen & Hernandez-Serrano, 2002). Designed to represent the case libraries stories in memory, studies on case library learning environments indicate previous experiences depicted in these environments play an important role in scaffolding learning by modeling decision-making and contextualizing knowledge (Choi & Lee, 2009; Hernandez-Serrano & Jonassen, 2003; Lajoie et al., 2014). When students in online learning have access to a library of cases that model disciplinary problem solving and suggest parts of solutions, interaction may be catalyzed as learners negotiate how to apply the principles to the main problem to solve (Bennett, 2010).

## 2.3. Failure-driven memory

CBR’s foundation rests in the ability to retrieve and reuse relevant cases when confronted with a new problem (Kolodner, Cox, & Gonzalez-Calero, 2005; Kolodner et al., 2004). CBR also posits that experts generate increasingly complex scripts as experiences are regularly encountered, which serve as a type of template for how to approach the problem. However, Schank (1999) argued that the script is not updated over time as homogenous cases are reencountered. In contrast to success cases, Schank’s (1999) theory of failure-driven memory suggested cases of failure better incite the learning process and update a script. Failure, thus, plays a central role in learning because it serves as a ‘mental warning’ (Gartmeier, Bauer, Gruber, & Heid, 2008) to modify one’s mental model (Ellis & Davidi, 2005). Whereas scripts help automatize the processing of problem solving, failure cases encourage the individual to engage in additional reflection and self-explanation of the causal reasoning that resulted in the error. Failure cases may also provide

opportunities to create new solutions and techniques, which would not have been triggered by cases of successful problem-solving (Hoeve & Nieuwenhuis, 2006; Parviainen & Eriksson, 2006).

A further investigation of errors affords the potential to develop a more complete understanding of the phenomenon; therefore, a mental model generated may be conceived as including both cases of successes and failures (Kolodner et al., 2004; Tawfik & Kolodner, 2016). To date, much of the learning through failure research discourse appears within workplace learning literature (Gartmeier et al., 2008; Gartmeier et al., 2010). Bauer and Mulder (2003) further noted that learning from failure cases is becoming more prevalent within complex work environments where practitioners are required to be responsible for an expanding body of knowledge. As such, research has documented that investigation of failure cases play a critical role in the fields of medicine (Gore, 2006; Rosenfeld, 2005), military defense (Ellis & Davidi, 2005; Ellis, Mendel, & Davidi, 2006), and software training (Keith & Frese, 2005, 2008).

### 3. Research questions

Online learning pedagogy should be implemented to “eliminate passive learner engagement and promote contributive learner involvement” (Oncu & Cakir, 2011, p. 1099). However, research has shown learners struggle to engage in the necessary learner-learner interaction important for effective PBL in asynchronous online learning (Ertmer & Koehler, 2015; Jeong & Joung, 2007; Oh & Jonassen, 2007). While various forms of scaffolds can be implemented, the challenge of overcoming the lack of problem-solving experience for novices still remains. To address this issue, the goal of this study was to understand the impact of success- or failure-based cases on learner-learner interaction. Specifically, our research question is as follows:

1. What are the effects of success/failure-based cases on various aspects of learner-learner interaction, if any?

### 4. Methodology

#### 4.1. Participants

Participants for this study were students enrolled in an online undergraduate course offered in the College of Business at a midwestern university, located in the United States. The course was entitled “Sales Management” and focused on how to hire, train, and retain optimal personnel for a sales team. A total of 74 (male = 32; female = 42) students were randomly assigned to 17 groups in an online section of the undergraduate business course. Each group consisted of 4–5 participants. Participants ranged in age from 19–22 years of age and were primarily English speakers.

#### 4.2. Procedure

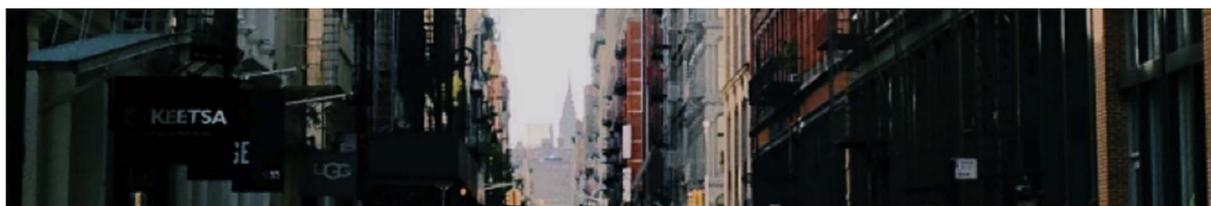
For the purpose of the experiment, the 74 participants were first randomly assigned to groups ( $N = 17$ ). The groups were then randomly assigned either the success or failure conditions (Success = 39 participants; Failure = 35 participants) using the Microsoft Excel randomization function. Each group was given a separate, private discussion forum to discuss the given problem to solve with only their group members. The participants stayed within their groups and conditions for the entirety of the experiment.

One week prior to the activity, the lead researcher used the Blackboard learning management system (LMS) announcement feature to inform students that an experiment was being conducted as part of a class activity. Although this activity was a graded part of the class, students were informed they could opt-out and complete an alternative assignment. All students agreed to participate in the experiment and signed the electronic Instructional Review Board (IRB) consent form.

The LMS presented the instructions and main problem to solve (i.e., Nick's Dilemma) in an identical way to all conditions in the LMS, with the only difference being the content of the related case library learning environments (success, failure). To begin the activity, participants were provided two days to read and reflect on Nick's Dilemma as well as the five related cases before engaging in discussion. The intent was to provide participants with adequate time to reflect on the materials rather than proceed directly to the discussion board. On the third day, each participant was required to post his/her initial thoughts regarding the issues, dilemmas, and initial answers related to Nick's Dilemma. Participants were also required to relate the case library learning environment to the main problem as part of their initial post and ensuing collaboration with their group members. A review of the discussion posts indicated that all students referenced the cases, suggesting that the cases were indeed accessed as the researchers intended.

In the days that followed, participants were encouraged to draw upon the cases in the case library learning environment to generate ideas to resolve Nick's Dilemma. After two weeks had passed, each group was instructed to develop a proposal presenting a solution to the main problem. The assignment required participants to include recommendations and supporting justification to solve the problem.

Upon completion of the assignment, discussion board posts were extracted and downloaded from the LMS for data analysis. These documents were then converted into a spreadsheet, and each of the discussion posts was divided into individual idea units. As others have noted (Strijbos, Martens, Prins, & Jochems, 2006; Weinberger & Fischer, 2006), idea units are dependent on the context and research questions. Given that our study explored the iterative nature of problem solving and learner-learner interaction, an idea unit was broken down when a) a transition in a participant's discourse (e.g., transitioning from initial agreement to a challenge) or b) a learner introduced multiple ideas in a given post (e.g., multiple suggestions for how to solve the problem). Thus, a single post could



Nick stepped into work Monday morning with his boss, Sheila. She scheduled this meeting to discuss a series of applicants that were being considered to fill a medical device sales position at AdvancedHeal left open after someone recently left to pursue another opportunity at another company. The company was small, but had interesting growth prospects.

"Nick", she begins, "we need to stop having to fill this position. It is us in terms of time and money to have to hire and train a new person every six months. We've had a lot of turnover in this medical sales position that needs to be stopped. As you know, we've missed on some of the previous hires. The three people we have had come in and out have cost us \$90,000 over the last year in terms of revenue and training. That's \$30,000 per person! The last individual hired for the position seemed pretty good in terms of technical expertise, but it was pretty clear that the sales aspect of the job wasn't a great fit. Let's go through some of these together and see if we can find someone with that right mix between [technical expertise and social skills](#)".

After going through the applicants, it becomes evident that it was difficult to find a great deal of qualified applicants.

"Oh man," Nick exclaims. "I didn't realize it would be this hard to find one person to fill a position. A lot of these people look really good on paper, but they just don't have the sales experience needed. They have decent schooling, but I want to make sure we bring in the right people. We could try to [retry posting a job ad in the St. Louis newspaper](#), but that costs us about \$1,500 per month. It's a risk shelling out all that money, but I think it's worth it if we get the right person rather than continuing to lose market share and have to constantly train new people. How about that list you have in front of you? Do you see any resumes that you like in particular?"

Sheila thumbs through some applicants. "Actually, here is one that seems pretty interesting. This individual, Lewis, has a decent GPA. It is about a 3.1 overall, but a 3.8 in classes related to his major. He also has [somewhat related experience](#) when he worked as a marketing intern for a children's hospital. Another option is try to [try to promote from within](#). That might only cost us \$15,000 to train a new person. I've heard great things about one employee in particular. This one employee, Terry, gets great telemarketing numbers in one of the worst territories for selling smaller medical devices. Plus, I know the supervisor in that department raves about Terry's character and leadership in that role. Although the experience isn't totally equivalent, it sounds like Terry has a chance to connecting with customers face-to-face."

Fig. 1. Embedded hyperlinks to case library.

be divided into multiple idea units. Other data collected included the thread name, the participant's group number, and the date and time of each discussion post. Posts from all three phases of the online activity were downloaded and used for analysis.

#### 4.3. Materials

**Main Problem.** Instructional materials for this study were adapted from a PBL module, entitled Nick's Dilemma (Tawfik & Jonassen, 2013). Specifically, the materials included a) a central sales management decision-making scenario and b) several related stories collected in a case library learning environment. The main problem to solve and the related case library learning environment were developed from the real-life experiences of an instructor with over 20 years of experience in sales management. The initial problem and subsequent decision-making scenarios were presented to the participants using a hyperlinked web page (see Fig. 1).

The main problem to solve depicted a situation wherein Nick and Sheila, the main characters, were hiring a new employee. The problem detailed the company's significant turnover, increase training costs, and market share losses. After reviewing resumes, Nick and Sheila are presented with a choice between two potential candidates, Terry and Lewis. Terry, was an internal candidate that worked in telemarketing, but did not have the ideal face-to-face sales experience. Lewis had related work experience and strong references, but intentionally misled Nick about a driving under the influence arrest that happened years prior. After reading the scenario, participants were required to solve the problem given the constraints and challenges of the context.

**Case Library Learning Environments.** The independent variable in the study was the type of case library presented to the participants - either success or failure cases. Each of the five narratives in the case library learning environment had the same characters and context for the narrative, but depicted different decision-making processes and outcomes. For instance, in the success-based case version of *Janice's Story*, participants read about an internal employee's promotion and its positive impact upon morale. In

## NICK'S DILEMMA

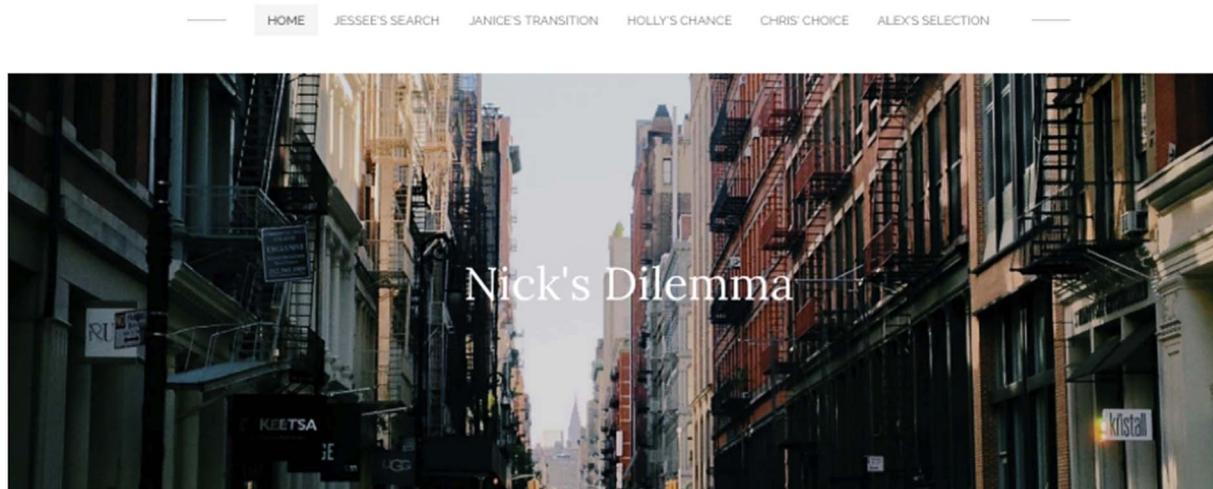


Fig. 2. Top Navigation Bar with access to cases.

the failure-based case version, Janice was passed over for a promotion and employee morale suffered. Participants were instructed to read each of the cases and leverage them to construct a solution with their group.

The activity was structured such that learners could access the cases within the LMS at various times. As participants read the main problem to solve, they were provided hyperlinks to the cases at strategic times. The hyperlinks were used to scaffold how the cases related to the main problem to solve (see Fig. 1). Previous research recommends this just-in-time approach, indicating that relevant labels for students to attribute to case assists with later case reuse and transfer towards the new problem (Kolodner et al., 2004; Tawfik & Kolodner, 2016). Participants could also access the cases from the top navigation bar using the titles of the cases that were provided (*Janice's Story*, *Chris' Choice*). In doing so, participants had an alternative method to revisit a case as needed (see Fig. 2).

#### 4.4. Measurements

The overall goal of the study was to determine how learner-learner interaction differed if participants were scaffolded using success- or failure-based cases when engaged in an online asynchronous PBL contexts. For the purposes of this experiment, learner-learner interaction was defined as collaborations between students (Moore, 1989). To understand the learner-learner interaction of participants, the data analysis employed a coding scheme adapted from Weinberger and Fischer (2006) and Hmelo-Silver and Barrows (2008) (see Table 1). Although the original schemes shared similarity, we combined the two because we believed each included distinct categories that are important to PBL. For example, Weinberger and Fischer (2006) included integration as a category, which described how another group member adopted an interaction from a peer. Alternatively, Hmelo-Silver and Barrows (2008) included additional categories focused about monitoring group work (meta). Given the importance of planning the final assignment, we believed that the meta, in particular, was important for the PBL activity. The final codes consisted of the following six categories:

#### 4.5. Coding scheme

Overall, the discussion board interactions were transformed into 1984 unique idea units. Once again, analysis included the entire online activity, with all three phases considered. Two research assistants were trained on the coding scheme and given examples for how to code specific idea units. The two research assistants then coded the idea units separately, and data were then analyzed for

**Table 1**  
Coding scheme.

Category	Description	Example
Externalization	Articulation of thoughts or unique ideas to a group	“If we do propose Terry, I really think we can use Janice’s story to back our case. Janice was a great salesperson working for AdvancedHeal. She always met or exceeded her sales quota and showed great leadership skills.”
Elicitation	Questions to clarify or provoke a reaction from other participants	“What other key issues are we trying to help Nick with? Will there be an emphasis on talent or trust within our hiring decision?”
Agreement	Acceptance of the contribution of a learning partner in order to move forward with the task	“I agree with you about hiring an intern to help with the situation. This will help save time, not only for Jesse but for Nick as well. The intern can focus more on carefully looking throughout the resumes and pick the best 5–10 candidates.”
Integration	Integration or application of peer perspectives	“I think your conclusion sentence does a good job of rephrasing the major dilemma of hiring Terry or Lewis. I would like to expand on this by saying that I think it is more worthwhile to hire Terry because while he lacks experience, he can learn everything he needs to know during training.”
Challenging	Disagreement, modification or replacement of perspectives of peers	“In regards to having a computer program filtering resumes, I’m personally against that. If you have a job opening that matters this much to the company, then I think its necessary to filter through each of the resumes manually. Someone may have a great resume, but used different words when describing their skills, and when using a computer, they wouldn’t get an interview when they rightfully should.”
Meta	Monitoring of collective of individual understanding and planning and coordinating the task	“This is very good insight to all of the counter arguments that could arise. From what I am gathering from our discussion thus far, it seems to be that these are our recommendations for Nick.”

areas of disagreement. The research assistants also had intermediate meetings with the lead researcher to ensure a similar understanding of the codes.

After the idea units were independently coded, the research group met to reconcile differences. If consensus could not be reached, a final discussion with the lead researcher resolved the coding disagreement. In total, the inter-rater agreement was 98%, with a final agreement of 100% after the final determination was made. After the two research assistants reconciled individual coding, each of the idea units was also reviewed by the lead researcher.

#### 4.6. Sequential analysis

The categories from the coding scheme (Table 1) were also used to perform a sequential analysis. As described by Bakeman and Gottman (1997) the objective was to examine which category of message followed each category of message. The sequential analysis allowed us to analyze the trajectory and patterns of their discourse; thus affording a more holistic view of the collaborative problem solving process when compared with the content analysis. First, we looked at each category of message (e.g., begin with externalization) and determined the category of message that followed (e.g., followed by elicitation) it in the success and failure conditions. Per sequential analysis, we then computed the percentage of messages in each category that followed the messages in each category (e.g. - the percentages of elicitations that followed an externalization). The calculations were normalized so that the sum of all transitions out of a category was equal to 1. The analysis was performed separately for messages in the success-based group and in the failure-based group. The relative difference between the groups was measured to determine the type of interaction that one group was more or less likely to engage in compared to the other.

## 5. Results

### 5.1. Content analysis

Descriptive statistics found the failure-based groups had a greater number of overall idea units (1046) when compared with the success-based groups (938). The participants in the success-based groups had an average of 26.15 (SD = 13.36) idea units, while participants in the failure-based groups had an average of 54.15 (SD = 25.51) idea units. An independent samples *t*-test found that the differences between the groups were significant ( $t = 5.78$ ;  $df = 72$ ;  $p < 0.001$ ).

Because the independent and dependent variables were categorical, the study employed a Chi-squared analysis design to identify differences within individual interaction categories. The content analysis allowed for further examination of the scope and nature of PBL interactions (Yap & Chia, 2010). Results of the analysis found participants exhibited different interaction types between the success- and failure-based groups ( $\chi^2, 70.59$ ;  $df = 6$ ,  $p < 0.001$ ). As highlighted in the results, a majority of the discourse focused on externalizations in both the success-based (63.2%) and failure-based (63.6%) groups. However, statistically significant differences between the success-based and failure-based groups emerged in terms of elicitation (STD Residual = 2.2) and meta (STD Residual = 5.0) interaction categories as evidenced by the standard residuals (Fig. 3).

A further analysis of the discourse showed that the participants used the cases, but in different ways. For instance, in the success version of *Jesse’s Case* (provided in the case library learning environment), the participants read about how ambiguity in the job placement text can attract a wider array of applicants from diverse backgrounds and encourage more applications. One participant

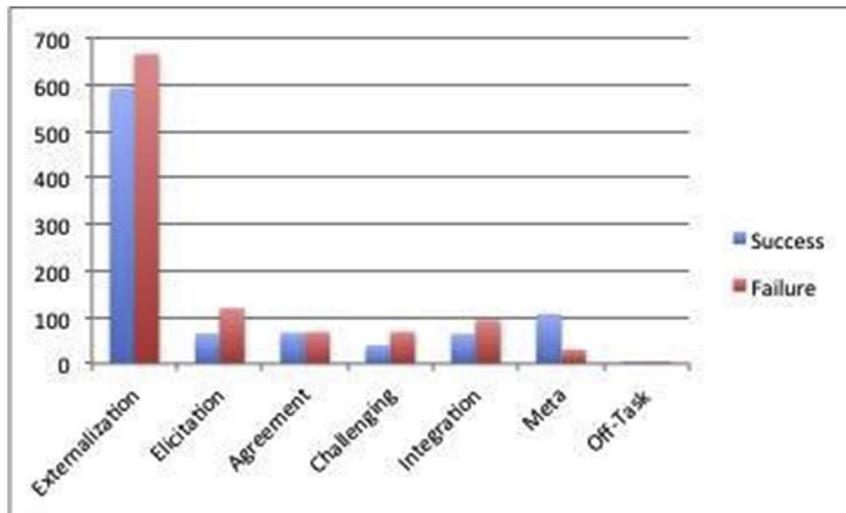


Fig. 3. Learner-learner interaction between success and failure conditions.

(note: pseudonyms used throughout) used the cases to suggest:

**Stacy (Externalization, Success Group 1):** *In the supporting cases they all had issues or better ways in looking for a qualified applicant to fill in the job positions, but help see the issues in Nick's case more clearly. In Jessie's case he decide[d] that it would be more effective if the job posting didn't have the company's name as a way to incite interest and make the post description intriguing.*

As described above, externalizations of the success-based groups often referenced the cases as a form of scaffold that helped generate ideas to solve the problem. Similarly, another participant shared with her group how one case helped frame her understanding of the problem:

**Angela (Externalization, Success Group 1):** *I feel that Jesse should have been less vague when providing the description of the job in order to avoid confusion or waste company resources on under - qualified applicants. Luckily for AdvancedHeal, Taylor's previous job experience was similar enough to not deter him away from AdvancedHeal's obscure job posting.*

The results also found that the success groups' focus built upon their peers' discussion of the cases, as depicted by the following sequence:

**Rob (Externalization; Success Group 4):** *Holly's Chance, Janice's Transition, etc, all prove that employees, when given the best opportunity and chance, can do a good job in their position. The more I think about it, I really do think that Nick could be the source of the dilemma.*

**Jason (Externalization; Success Group 4):** *As for Nick, it seems he finds Lewis very similar to Alice, whereas Lewis is experienced in the workforce and can possibly bring something different to the company, rather than hiring internally. Upon his interview with Lewis, he finds his demeanor and knowledge very appealing. On the downside, Nick found out that Lewis had a DUI charge a few years back that goes against the company's policy with hiring people with moving violations for a company car.*

In the above example, the initial post abstracted ideas from a series of cases, while the response focused on how an individual case (Alice's Selection) could be used to solve the main problem to solve. Once again, the success-based cases seemed to help support problem representation and ideas for solution generation, which were largely agreed upon by their other members.

In contrast to the success-based examples, those in the failure-based cases appeared to show a greater proclivity to discuss the details and nuances of the case. Specifically, the additional discussions focused on causes of the failure, potential remedies, and how the lessons learned could be transferred to the main problem to solve. For instance, the participants referenced the failure version of Jesse's Search and how the ambiguity of the job placement verbiage wasted time and resources:

**Kelly (Externalization; Failure Group 15)** *I was very confused and alarmed when Jesse decided to take the name of the company off of the ad, it doesn't make any sense! I would have definitely tried to spruce something up to make up for the lack of applications coming in, but having the company title on is essential - she might as well not have written in the job title either. (Elicitation) What do you guys think would be a good thing to include/exclude to try to get Jesse's applicants numbers to rise?*

In contrast to the success-based groups, the participants in the failure-based groups not only shared their assessment of the case, but also ideas about how they would resolve the error. Moreover, the initial post about the case also served as an opportunity to ask if her peers understood the case in the same way (elicitation), as opposed to just an externalization of an idea. Keri, in Group 2, showed a similar form of causal reasoning as to why the failure occurred. Rather than progress towards completing the assignment, she also transitioned to an elicitation to invite others to reflect, understand the failure case, and question about how to transfer the lessons learned:

**Keri (Externalization; Failure Group 2)** *Hey guys so I've been reading a lot of the other tabs [cases] and I think they all play into Nick's Dilemma a lot. If we do propose Terry, I really think we can use Janice's story to back our case. Janice was a great salesperson working for AdvancedHeal. She always met or exceeded her sales quota and showed great leadership skills. When a sales management position verbally submitted an application to be considered for the position. Her boss ended up hiring a man out of retirement who worked in another industry to revamp the sales team. Janice was shocked, and she told her boss, Sanjeev, that she knew it would cost the company more to hire in another person who is less qualified. They hired the retired man anyway. The motivation of her peers started to suffer (they did not trust the new hire after a capable peer like Janice was passed over). (Elicitation) Doesn't this sound extremely familiar to the Terry and Lewis situation? We could say there is a chance, as seen in past circumstances, that looking over a capable and popular person like Terry for a new hire that has a DUI may cause unrest in the work environment and create a lack of trust between employees. What do you think?*

Due to different interpretations about why the failure occurred, participants in the failure condition also seemed more willing to challenge their peers' interpretations of the case and ask further questions about the lessons learned from the case. For example, Group 7 posited the following exchange when talking about posting a newspaper advertisement for the job:

**Teegan (Externalization; Group 7):** *This could draw a much larger crowd so that the job pool would be more diverse and hopefully contain a potential hire that Nick would be happy with. Although this would cost an additional \$1500 a month, I think it would be worth it. It could only take one month to find a new employee. That way the company only spends the extra \$1,500, and doesn't have to continually worry about training and hiring fees. They would need to ensure during the interview that the potential employee would be willing to put in a few years to the company and would be loyal.*

**Jason (Challenging; Group 7):** *I had a little different take away from Jesse's search because I feel it shows the difficulty of a newspaper advertisement. She showed that if you are too vague in the job description you get too many unqualified applicants, and on the other hand, if you are too specific with the job description you won't attract many applicants. Therefore, I am not sure it is in Nick's best interest to run a newspaper advertisement because it won't be worth the cost.*

Once again, participants appeared more likely to challenge the causal reasoning and interpretation of their peers as to why the failure in the case occurred. Similarly, a participant in Group 14 used the lessons learned in the failure cases to challenge a solution by a group member about whether to reopen the position:

**Deepak (Challenging; Failure Group 14):** *I think you make a really good point about the price of the ad, however I wonder how else they would advertise the position without it. In the past, simply filling a position through word of mouth or by someone they know has not worked out for the company. This is shown in both Alex's selection and Chris's choice when they pick someone they know or someone in the company knows, instead of completely branching out and hiring someone who is not connected to the company. One way Nick could satisfy both the price issue of placing an ad and making sure qualified people hear about the ad could be finding a more cost efficient way to promote the opening (ex. flyers).*

Even when a lesson was initially shared with the group and applied to the new problem, participants were willing to challenge positions about how to transfer the solution based on the different perspectives as to why the failure occurred.

### 5.2. Sequential analysis

To further understand patterns of learner-learner interaction, we conducted a sequential analysis. This allowed us to ascertain what type of learner-learner interaction category followed a particular statement. After the idea units were coded, we imported the results in Tableau software to visualize the interaction types and groups. As shown in Fig. 4, colors were used to show relative differences between interaction types (red = greater gap, blue = smaller gap).

Similar to the Chi squared analysis, differences emerged between groups. For instance, after receiving a challenge, the failure group transitioned to a meta stage 4% of the time. However, the success group responded to a challenge with a meta response 16% of the time. Once again, the meta stage was described as planning for the final assignment. The results suggest the differences were greater in the challenging, elicitation, externalization, and meta categories. The greatest degree of difference occurred in how often a

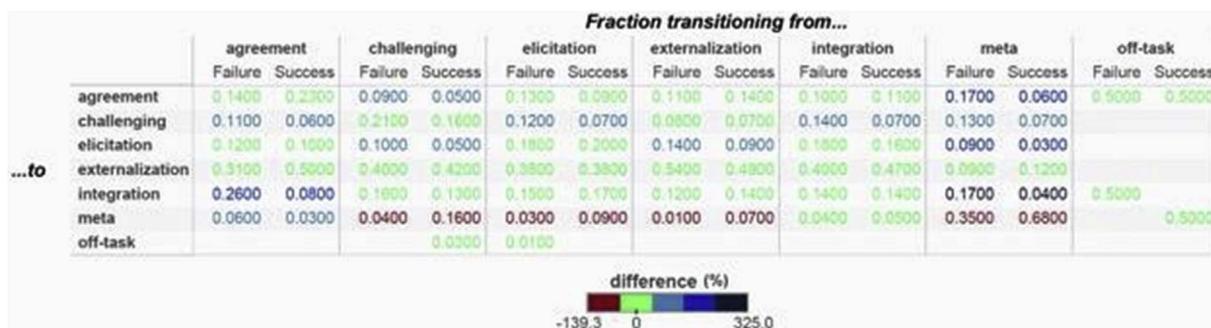


Fig. 4. Sequential analysis.

meta was followed-up by another meta response. That is, participants in the success condition seemed to more quickly transition to finalizing their assignment 68% of the time. Those in the failure condition, alternatively, were willing to revisit other types of interactions (e.g., externalization, elicitation) even if their peers had transitioned to a meta/planning comment.

## 6. Discussion and implications

To overcome the challenge of interaction in asynchronous online PBL contexts, various scaffolds have implemented question prompts, wikis, and discussion starters. While cases that depict the experiences of experts is an important scaffolding strategy, research has yet to examine what types of experiences should be employed to scaffold meaningful interaction during PBL. To understand the role of design using case libraries, this study measured differences in success- and failure-based interactions in terms of externalizations, elicitations, agreements, integrations, challenges, and meta comments. As shown by the independent samples *t*-test, the failure group had statistically significant higher overall idea units when compared with the success group. To further explore those differences, we employed a Chi squared analysis and sequential analysis. One finding indicates that success and failure cases are useful sources to share ideas, as evidenced by the number of externalizations in each group. Although both conditions seemed to exhibit a similar pattern in terms of the distribution between externalizations, agreement, challenges, and integrations, statistically significant differences were found with the elicitation and meta categories. While one might argue the increased number of elicitation suggests the failure cases are more difficult to apply, the content analysis suggests the failure case encouraged learners to explore the details of the narrative and incite discussions about how the lessons learned might be transferred to the main problem to solve. Furthermore, investigation of the discussions from the failure group suggests the elicitations focused on causal reasoning about how to explain and remedy the failure.

The interpretation of the differences in the meta category may be explained by other analyses conducted. By visualizing the sequential analysis, we were able to understand the relative weight of interaction patterns between groups. Specifically, we found the largest differences between groups were in the meta category. That is, when learners in the success group had begun concluding their project, they were more likely to stay engaged in planning and finalizing their project 68% of the time. These findings are similar to other research, which has suggested learners are unlikely to iterate their problem solving when they have focused on a solution (Ertmer & Koehler, 2014; Oh & Jonassen, 2007). Alternatively, those in the failure condition responded with another meta comment only 35% of the time. Specifically, participants in the failure group were more likely to share additional ideas, questions, and challenge each other after a peer had begun planning.

This study has multiple implications for learner-learner interaction, PBL, CBR, and failure-driven memory. An important part of any PBL setting is that it provides a joint task requiring learner-learner interaction to define the problem, generate hypotheses, and identify knowledge gaps (Jeong & Hmelo-Silver, 2016). To date, PBL has also been implemented using different modalities, such as face-to-face, hybrid (Tambouris, Zotou, & Tarabanis, 2012), and asynchronous online learning (Brown et al., 2013; Donnelly, 2010). While research on PBL and online learning has shown promise, many studies focus on learning outcomes “without exploring their problem-solving strategies and patterns of behavior related to cognitive processing” (Lin et al., 2014, p. 52). Even when learner-learner interactions have been studied, findings suggest that learners in online PBL are not likely to challenge the assertions of others or ask meaningful questions that build on the contribution of their peers.

This study also provides additional support for case-based reasoning theory (CBR) and contributes to the limited research on failure-driven memory theory as a way to catalyze learner-learner interaction in PBL. Because students lack experience, researchers have suggested novices spend more time trying to decipher a situation, fail to properly represent the problem, and focus on extraneous information they believe will solve a problem (Fitzgerald et al., 2011; Schwartz, Weiner, Harris, & Binns-Calvey, 2010). To overcome these challenges, others have argued cases help address the lack of experience gap (Dabbagh & Dass, 2013; Kolodner et al., 2003). For instance, Jonassen (2011a) asserted, “cases are the building blocks of [all] problem-solving learning environments (PSLEs)” (Jonassen, 2011a, p. 149). This study thus provides some evidence on the impact of cases on interaction in online PBL contexts. Results of the content analysis indicate when cases include not only what happened, but the rationale used to understand a situation, make choices, or solve a problem, cases can help support problem representation when students lack experience.

As shown above in the content analysis, both success and failure cases helped to provide ideas about how to solve the problem, as evidenced by the number of externalizations. While the study found both success and failure cases can be used in PBL contexts to help incite meaningful learner-learner interaction, the failure cases, in particular, engendered additional elicitations among peers and explored how the lessons learned from the failure could be transferred to solve the problem. As stated previously, failure is an important part of the problem-solving process, but is often eschewed (Tawfik, Rong, Choi, 2015). In terms of failure cases, this study provided empirical support for Schank's (1999) assertion, “dynamic memory is always changing as each processing failure causes learning to take place” (p. 47). In failure cases it is not always clear why the error occurred, which encourages learners to engage in additional inquiry as to why the failure happened and how to avoid it in the future (Kolodner et al., 2004). By introducing stories of failure, learners in the current study appeared to reflect on the important causal details that might be otherwise overlooked by novices. While other forms of scaffolds such as wikis (Ioannou et al., 2015) or question prompts (Ge, Planas, & Er, 2010) have been implemented in online PBL settings, this study found failure-based scaffolds could encourage learners to ask meaningful questions of their peers during problem solving.

## 7. Conclusion

CBR theory suggests that individuals will retrieve prior experience based on a set of indices (labels) from memory when presented

with a new problem. If applicable, the individual will then reuse the lessons learned in order to inform a solution. While content analysis indicates both types support interaction, this study's results suggest failure-based cases, in particular, may incite interactions such as elicitations. The sequential analysis also revealed that learners in the failure condition were more likely to continue their collaborative problem solving, as evidenced by the meta category discrepancy.

There are multiple ways to build upon this study. While these findings stem from an online asynchronous PBL context, future studies could explore whether this phenomenon can be replicated in a face-to-face educational setting as well. This would provide further evidence regarding the efficacy of failure-based cases to incite specific types of learner interaction. Others may also build upon the current study by exploring different combinations of success and failure. Indeed, much research has explored the benefits of contrasting cases (Roelle & Berthold, 2015; Schenke & Richland, 2017), but has yet to be studied within asynchronous PBL contexts. It is possible that learners may have approached the problem solving differently if afforded an opportunity to compare success and failure directly. This, in turn, may have impacted how their learner-learner interaction took place.

The current study was also situated as a decision-making problem in an undergraduate business course. It is unclear how these results may transfer to other disciplines, such as medicine or engineering. Since those disciplines have unique constraints and problem types, further studies could explore the degree to which these results can be replicated in different domains.

Finally, additional research could explore this phenomenon across different age groups. While the study was conducted in a higher education context, it is possible that the failure-based cases may not be obvious to learners with differing levels of prior knowledge. One might also argue that younger learners require models, which are more present in success-based cases. If the results are replicated, this could provide further evidence as to the merits of failure-driven memory.

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