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**Strategies to Improve Collaboration**  
**in a**  
**Problem-Based Learning Environment: Alien Rescue**

**APPROVED BY**  
**SUPERVISING COMMITTEE**

**Supervisor:** \_\_\_\_\_  
Min Liu  
\_\_\_\_\_  
Lucas Horton

**Strategies to Improve Collaboration**  
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**Problem-Based Learning Environment: Alien Rescue**

**by**  
**Sukanya Kannan Moudgalya, B.Tech.Industr.Bio.**

**Report**

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## Dedication

To my parents.

## Acknowledgement

I would like to thank everyone who helped me through my Master's degree and encouraged me to write a report. In particular, I want to thank Dr. Min Liu for being an inspirational, encouraging, and a motivating adviser. Her mentorship has helped me more than I can express through words. I would also like to thank Dr. Lucas Horton. His advice, guidance, and humor, helped me a lot while writing this report.

I deeply appreciate my parents' support in everything I do. Without them, I would not be where I am today. Thank you for always believing in me, no matter what I choose to do.

To my friends in Austin who have encouraged me, made me laugh, had friendly conversations with me- Thank you. Your support has helped make graduate school a wonderful experience.

# Abstract

## **Strategies to Improve Collaboration in a Problem-Based Learning Environment: Alien Rescue**

Sukanya Kannan Moudgalya, MA  
The University of Texas at Austin, 2017

Supervisor: Min Liu

Abstract: There is an ever growing need to research and develop pedagogical strategies that cater to the 21st-century skills. Problem-Based Learning (PBL) is one such instructional strategy. There are currently many PBL environments, but for this report, I use a PBL environment called ‘Alien Rescue’ as an example. PBL has many goals that it wishes to achieve. In this report, I highlight the importance of five such goals. I then review the practices in Alien Rescue to see which goals it supports the best and which goal could need improvements. I then choose to focus on one of the very important goals, namely, collaboration. I again review the literature to find strategies that support collaborative learning in PBL. Finally, I contextualize these strategies to Alien Rescue. I make specific suggestions that will improve collaboration, offer implementation tactics for these suggestions, and also give ways to evaluate the effectiveness of the suggestions in Alien Rescue. I hope to help in the research and development process of Alien Rescue with this report.

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# Chapter 1

## Introduction

There is an urgent need to ensure that today's students are able to apply what they have learned in real-world contexts. It is now widely recognized that the future generation needs to be prepared to face the ever growing, fast paced, digital, 'information' age. This means that educators, researchers, and policymakers need to focus on methodologies that will impart students the skills required for the 21st century. Many innovative methodologies are now being researched and used in schools to address this need.

One such teaching and learning methodology is called Problem-Based Learning or PBL. PBL is considered to be an instructional strategy that is rooted in constructivism. It also is supposed to engage students in tasks that are authentic to the environment in which they will actually be used (Savery & Duffy, 1995). Problem-Based Learning (PBL) was first introduced formally in medical education in the 1950s. It was introduced to address the poor clinical performance of medical students. The medical educators realized that students should be prepared for clinical problem solving and lifelong learning (Barrows, 1996; Hung, Jonassen, & Liu, 2008). In the 1980s, the use of PBL in medical education became widespread due to the GPEP report (Report of the Panel on the General Professional Education of the Physician and College Preparation for Medicine). Later, in the 1990s, it gained popularity in K-12 settings as well (Hung et al., 2008).

Problem-Based learning focuses on group learning and can be thought of as a small group teaching method. It thus encourages teamwork, problem-solving, sharing information, communication skills, respect for others' opinion, etc (Wood, 2003).

Barrows (1996) defined PBL as a methodology that promoted the following:

1. Student-centered learning
2. Small group learning

3. Teachers as facilitators
4. Problems that form the stimulus for learning
5. Problems that lead to clinical problem solving
6. Self-directed learning (p. 5)

These ideas are more directed towards medical education. Hmelo-Silver (2004) described PBL as a methodology that leads to the following, more general, goals:

1. Construct an extensive and flexible knowledge base
2. Develop effective problem-solving skills
3. Develop self-directed, lifelong learning skills
4. Become intrinsically motivated to learn
5. Become effective collaborators (p. 240)

Intuitively, these five goals seem very important for effective learning. From the literature, there is definitive evidence that demonstrates the importance of these objectives. There are also many indicators that show how PBL will benefit from these goals. Both of these will be addressed in the following chapters.

## **1.1 The purpose and structure of this report**

The five goals that Hmelo-Silver (2004) mentioned above are crucial to PBL. When one designs PBL environments, it is important to ensure that these goals can be supported. In this report, I will use the 3D PBL environment ‘Alien Rescue’ (AR) as an example of a problem-based learning environment. Alien Rescue (AR) is developed by researchers at the University of Texas at Austin (*Alien Rescue - Official Site*, 2017).

In this report, I intend to identify how well AR supports each of the five goals. I will then focus on any goal that is not supported very well. Once I narrow down on such a goal, I will review the literature to suggest methodologies that can improve AR in terms of that goal. The steps below will help me address my aims for this report:

1. With evidence from literature, support the importance of each of the five goals in relation to PBL.

2. Identify the design and pedagogical elements in Alien Rescue that support the five goals.
3. Review the literature to see what design and pedagogical strategies have been used to support these goals. I will be focusing specifically on collaborative learning, goal five.
4. Suggest design and pedagogical strategies to improve goal five (collaboration) based on findings from objectives (2) and (3).
5. Recommend methodologies that would help in implementation and the evaluation of the effectiveness of these strategies.

To address these five steps, my report is designed in the following way. **Chapter 1** ('Introduction') gives an introduction to PBL and describes some goals that PBL achieves. **Chapter 2** ('Design and Pedagogical Elements in Alien Rescue that support PBL') will address steps 1 and 2 **Chapter 3** ('A Literature Review of strategies to increase collaboration in PBL environments') will focus on step 3. **Chapter 4** ('Design and pedagogical suggestions to increase collaboration in AR') will focus on steps 4 and 5.

Please note that by pedagogical strategies, I mean elements that support learning outside of the actual gaming environment. This would include the classroom and social environment, teacher instructions and facilitation. The design strategies include elements that are directly embedded in a game or learning environment. These are 'objects' that can be iteratively redesigned depending on the needs of the learning environment.

## 1.2 Significance of this report

Alien Rescue is a constantly developing and evolving learning platform. It is now in its sixth version. Both designers and researchers work together using design-based research to create Alien Rescue. The project model starts with concept and design, then progresses to development, and lastly implementation for each version. Planning and evaluation are included in each step and overall (Liu et al., 2014). I hope that this report provides some ideas for *concepts* for the next versions of Alien Rescue. In a broad sense, I cover aspects of 'concept' in the second and third chapter. I also cover aspects of 'design and development' and 'planning, implementation, and evaluation' in the fourth chapter.

## Chapter 2

### Design and Pedagogical Elements in Alien Rescue that support PBL

As mentioned in the previous chapter, I will be focusing on AR as the PBL environment in this report. Alien Rescue is a 3D, immersive, multimedia PBL environment. It is also a serious gaming environment. It designed to address the TEKS (Texas Essential Knowledge and Skills) for sixth-grade science. It is used by sixth graders in many states in the United States and also many different countries. Alien Rescue encourages students to role-play as scientists so that they can relocate six alien species, who have lost their own homes, in our solar system. To accomplish this, students use cognitive problem-solving tools. For instance, they use databases to look up pre-existing information, gather new information by sending probes, while managing budgets to do so. Later, they assess all data, hypothesize suitable home planets for the aliens and rationalize their hypothesis. During this entire process, the teachers act as facilitators. Thus, one can easily see how Alien Rescue supports cognitive inquiry and problem-solving methodologies in students (Bogard, Liu, & Chiang, 2013). The following few sections describe how Alien Rescue supports the five goals mentioned in the first chapter. In addition, I also elaborate the importance of each goal.

#### 2.1 Helping construct an extensive, flexible knowledge base:

Having the ability to have a flexible knowledge base allows students to approach even new and unknown problems with ease and solve them. The ‘Cognitive Flexibility Theory’ talks about how learning, or knowledge acquisition, occurs in ill-structured domains. Since PBL and real-life problems are ill-structured, this theory becomes important to understand. Spiro (1988) mentioned that compartmentalization of knowledge and having a rigid knowledge or mental structures can act as deterrents to creating new knowledge and solving new problems. He mentioned that

it is crucial to move away from *retrieving* information from a rigid mental schema and instead be flexible, moving towards *assembling* knowledge structures from various precedent case sources. This would help students be adaptable and address novel situations at hand. Bransford and McCarrel (1974) demonstrated that students indeed need to have a good ‘prior’ knowledge base for effective recall and comprehension. In addition, this knowledge must be relational or have non-isolated individual components, be activated properly, and also be applied to appropriate contexts. One way to activate this knowledge base is by small group discussions of the problem, as proved by Schmidt, Volder, Grave, Moust, and Patel (1989). Thus, we see how PBL will benefit from this goal, and why this goal is important for learning in the 21st century.

### **How Alien Rescue supports this goal:**

To help students address the ‘problem’ at hand, Alien Rescue provides many cognitive tools. These cognitive tools were developed so that students have some scaffolding while they solve problems. The tools that can specifically help build and maintain a good knowledge base are (1) tools that support cognitive load and (2) tools that share cognitive process (Liu et al., 2013). The first set of tools, for example, concepts tool, databases tools, glossary, etc, provide information to students in a distributed manner, extending their existing knowledge base. The second set of tools includes the notebook tool with comparison features. This helps students integrate information from different sources and compare them. For instance, with the help of the notebook tool, students can compare specific features of a planet with that of an alien. This helps in decompartmentalization of knowledge. Please refer to Figure 1 to see how the notebook is designed to accommodate this.

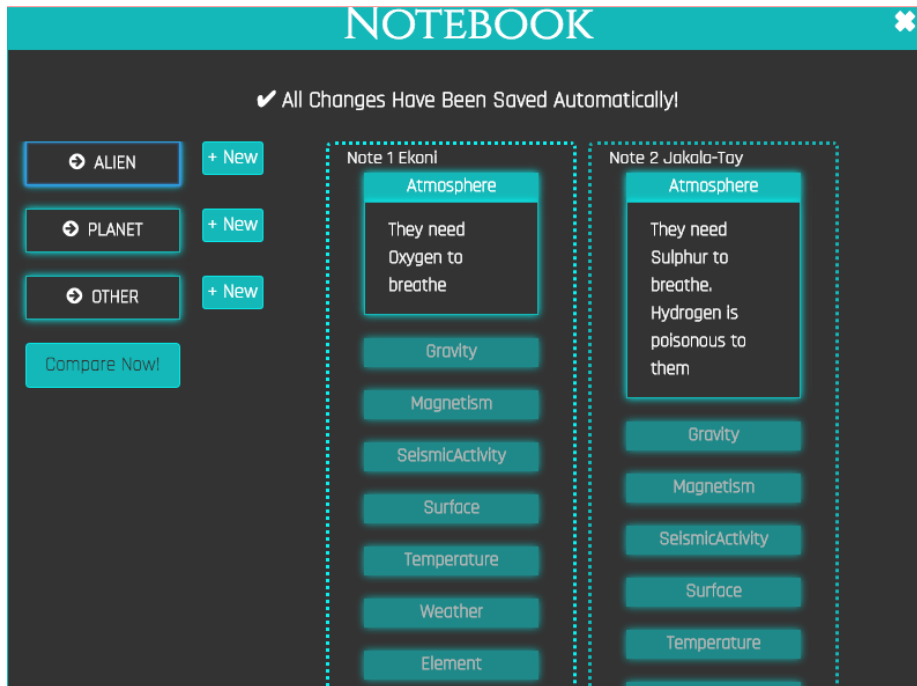


Figure 1: The Notebook tool in Alien Rescue

## 2.2 Assisting problem-solving strategies:

As mentioned earlier in the chapter, it is important for students to learn to address and solve real-world problems. Hmelo-Silver (2004) mentioned that using appropriate metacognitive reasoning strategies, such as hypothetico-deductive reasoning or case based analogies, is important for problem-solving. In particular, Lawson (2000) illustrated that using hypothetico-deductive reasoning is important for the sciences and for the solution for practical human problems. Hypothetico-deductive reasoning requires students to make ‘If ... and ....then... And/But ... Therefore ...’ arguments in order to solve problems. Mandin, Jones, Woloschuk, and Harasym (1997), however, expressed that this methodology is mostly used by novices. According to them, experts used ‘schema-driven search strategies’ to solve problems. They also made a strong case for using this strategy in PBL. Overall, it seems as though metacognitive approaches, such as the ones mentioned above, are important for problem-solving and PBL. Indeed, Swanson (1990) proved using experiments that students with higher metacognitive ability could solve problems better than students with lower metacognitive ability, regardless of their aptitude. Thus, we see how PBL will benefit from this goal, and why this goal is important for learning in the 21st century.

### How Alien Rescue supports this goal:

As mentioned in the previous section, Alien Rescue has many cognitive tools

embedded that helps students. Apart from the tools already mentioned, Alien Rescue also has tools that support otherwise out-of-reach activities (such as probe designing) and tools that support hypothesis testing (such as the messaging tool, solution form, mission control) (Liu et al., 2013). Together, these tools helped students in the problem-solving process (Liu et al., 2009). In fact, students used tools depending on their stage of problem-solving. For instance, they used tools that share support cognitive process when understanding the problem. When they were on the identification, gathering and organizing stage, they used mostly used tools that provide otherwise out-of-reach activities, such as the probe. Later, when they wanted to double-check their responses, they would go back to using cognitive support tools. Indeed, Bogard et al. (2013) explained how successful problem solvers focused on the cognitive processes within each threshold or stage of problem-solving, and then progressing from one threshold to the next. From Figure 2, one can observe how the cognitive tools in Alien Rescue would support activities within each threshold. The official Alien Rescue teacher's manual suggests that teachers should talk to students about the problem-solving process before the students start playing the game. It encourages students to have goals and plan of action in mind to assist problem-solving. After they play the game, debriefing sessions encourage them to reflect on their learning. Thus, we see both design elements and pedagogical elements that will support problem-solving.

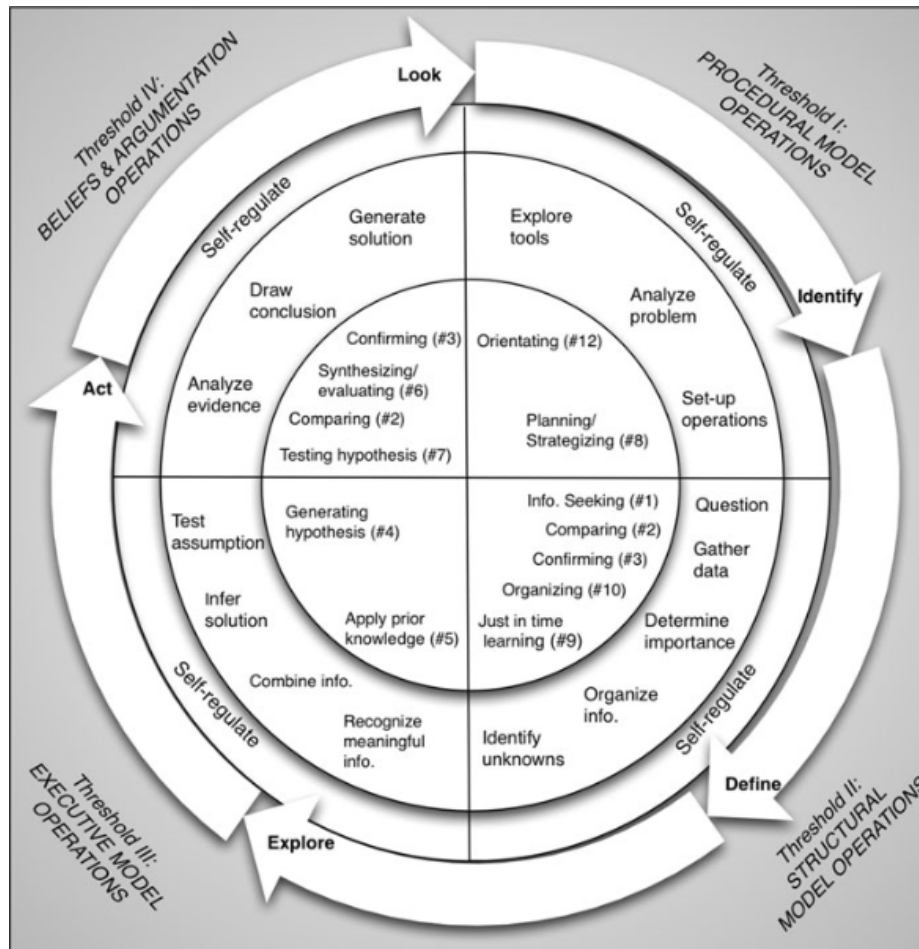


Figure 2: The Thresholds of Knowledge Development. Reprinted from ‘Thresholds of knowledge development in complex problem solving: A multiple-case study of advanced learners’ cognitive processes’ by Bogard et al. (2013), *Educational Technology Research and Development*, 61(3), p. 491.

### 2.3 Creating self-directed, lifelong learning skills:

Self-directed learning is often considered an essential part of adult learning theories (Merriam, 2001). These days, however, it is also thought to be important for younger students. Bolhuis (2003) related self-directed learning to ‘lifelong learning’. In addition, she presented four arguments that demonstrated the need for self-directed learning. These were :

- Self-directed learning would lead to students at lower school levels be prepared for the higher, ‘next’, educational levels.
- Self-directed learning would lead to economic benefits, due to production and use of new knowledge.
- Self-directed learning would lead to students being members of a ‘global village’ and appreciate differences of opinion.
- Self-directed learning has the potential to lead to a truly democratic society that promotes equality (p. 328).



In addition, students who went through self-directed learning methodology with proximal subgoals demonstrated mastery, self-efficacy, and intrinsic interest in the subject of interest (Bandura & Schunk, 1981). Moreover, evidence has shown that students who undergo PBL strategies exhibit self-directed learning skills (Evensen & Hmelo-Silver, 2000). Thus, we see how PBL will benefit from this goal, and why this goal is important for learning in the 21st century.

### **How Alien Rescue supports this goal:**

Pedagogically speaking, Alien Rescue encourages students to explore and learn on their own in the environment. Teachers are supposed to be facilitators. In addition, Liu, Cho, and Schallert (2006) mentioned the following: “An optimal self-directed, technology-enhanced environment is one in which students have the autonomy and are willing to explore, knowing that support, resource, and guidance are available when needed”. Alien Rescue is one such learning environment. Within the context of Alien Rescue, this self-directed approach increased students’ self-efficacy, performance, and science achievement (Cho, Liu, & Schallert; Liu et al., 2006). Liu et al. (2006) also made a strong case for why teachers should consider using non-direct methods of teaching. Moreover, the teachers are encouraged to help students think about their future, if they would choose science as a career, how they would relate the problem-solving strategies learned through Alien Rescue to real-life problems. Thus, we easily see the pedagogical elements that support self-directed learning.

### **2.4 Sparking intrinsic motivation:**

Motivation is considered very important for students. Intrinsic motivation, particularly, is considered extremely important. In fact, Ryan and Deci (2000) said that “Perhaps no single phenomenon reflects the positive potential of human nature as much as intrinsic motivation, the inherent tendency to seek out novelty and challenges, to extend and exercise one’s capacities, to explore, and to learn ” (p. 70).

Many examples and experiments reflect this statement. Intrinsic motivation has positively affected text comprehension, processing, test performance, persistence, etc, in participants of controlled experiments (Kuvaas, 2006; Vansteenkiste, Simons, Lens, Sheldon, & Deci, 2004; Wang & Guthrie, 2004). The participants in all these studies represented a diverse group that included elementary school students, high-school students, college students and also working professionals. Thus, we see how

PBL will benefit from this goal, and why this goal is important for learning in the 21st century.

### How Alien Rescue supports this goal:

When designing Alien Rescue, the researchers ensured the incorporation of elements that are traditionally considered to increase motivation. Some of these elements include authenticity, challenge, curiosity, fantasy, etc (Liu, Horton, Olmanson, & Toprac, 2011). Figure 3 describes how these elements relate to the motivational perspectives. Also, this study found that majority of the students were motivated to use Alien Rescue after playing it. 61% of the students responded that they like Alien Rescue more compared to other activities. Additionally, the most commonly used word to describe Alien Rescue in an open-ended question was ‘Fun’. In another study by Liu (2005), students had higher science test scores, intrinsic goal orientation and a better attitude towards science after playing Alien Rescue.

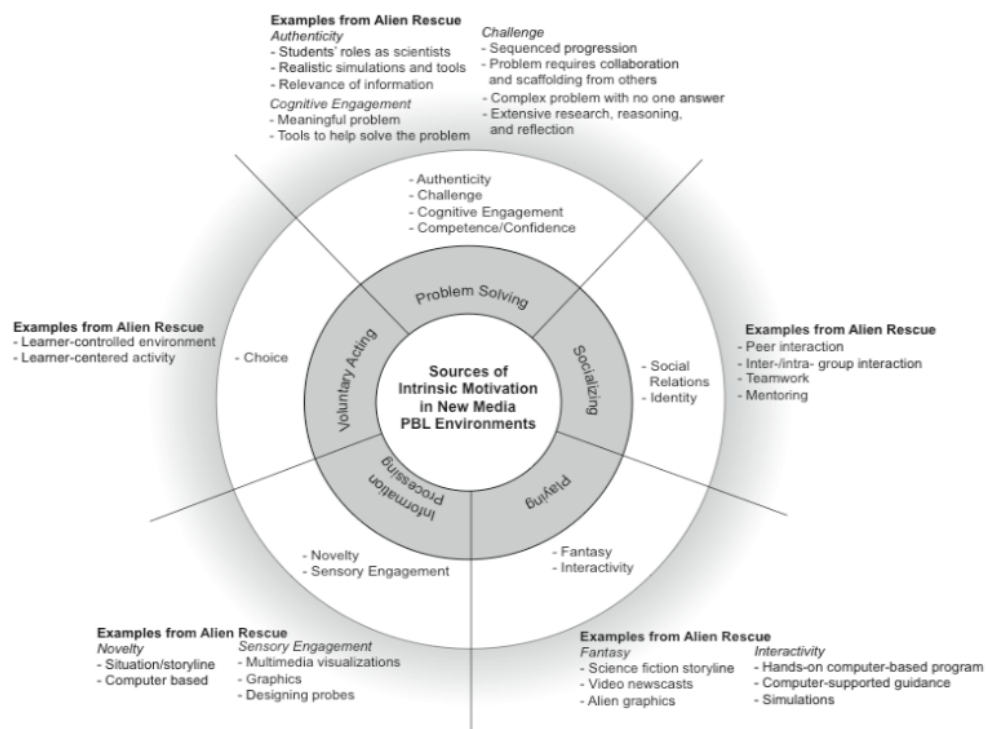


Figure 3: Motivating elements in Alien Rescue in relation with Motivational perspectives. Reprinted from ‘A study of learning and motivation in a new media enriched environment for middle school science.’, Liu et al. (2011), *Educational Technology Research and Development*, 59(2), p. 252

### 2.5 Fostering collaborative techniques:

Collaboration is also considered an important skill. Social constructivists believe that collaboration leads to co-construction of knowledge, and this knowledge

is affected by both individual and social (group) processes (Palincsar, 1998). They also believe that group dynamics, such as social status, engagement and expert assistance affect collaboration. Moreover, Oxford (1997) suggested that collaborative learning is related to ‘knowledge communities’. She said that in addition to having social constructivist roots, it is also related to cognitive apprenticeship and the zone of proximal development. There is often an ‘expert’ involved in the group.

The social interdependence theory suggests that ‘cooperation’ is also extremely important for collaborative learning. Johnson (2003) mentioned that from more than 700 empirical studies, the data show that compared to competitive or individualistic learning, cooperative learning lead students to invest higher efforts during projects, create positive relations and social support, and experience higher rates of self-esteem.

Cooperative learning is quite similar to collaborative learning. Both cooperative learning and PBL have underlying concepts of interdependence (Smith, Sheppard, Johnson, & Johnson, 2005). But, one of the major differences is that cooperative learning also requires individual accountability (Oxford, 1997). She also suggested that cooperative learning, in general, is more structured, organized, and is very applicable to K-12 learning environments. But, she mentioned that these two terms are often not differentiated by researchers, which in her opinion is wrong. Keeping this in mind, for the purpose of this report, I prefer using the keyword ‘collaboration’, as it is the term used in ‘goal five’ of PBL. But, I also plan to use the term ‘cooperation’ during my literature review so that I can cover more ground when researching about group dynamics and interactions for better learning.

All in all, from this section we see how PBL will benefit from this goal, and why this goal is important for learning in the 21st century.

### **How Alien Rescue supports this goal:**

The teachers’ manuals and lessons plan have mentioned that the teachers should encourage students to collaborate. The manuals have also specified that teachers give popular examples of scientific collaboration, such as Dr. Frankenstein. Moreover, the manuals have encouraged teachers to direct students to ask help from their classmates, rather than the teacher themselves. Additionally, there have been clear indicators that the students liked to help each other while playing Alien Rescue. For instance, some students who had played Alien Rescue previously ended up telling the new students valuable information about the game (Liu et al., 2011). The researchers

attributed this to the ‘playful’ nature of the environment in which students have authentic roles combined with meaningful activity. This feature also seems to be related to social constructivism.

## **2.6 Reflections on the design and pedagogical elements:**

From the findings of this chapter, it is clear that Alien Rescue already has many elements that will support the five goals. One can always, however, explore scopes for improvement. This is especially because Alien Rescue supports some of the goals more strongly than others. Currently, creating a collaborative atmosphere is left mostly up to the teachers. Although the teacher’s manual encourages collaboration, there is no explicit pedagogy on creating a collaborative atmosphere. In other words, Alien Rescue as an environment does not have specific collaborative features. This can be especially problematic, as teachers would need to invest their own time and be comfortable with fostering collaboration without a detailed guidance. Thus, I am interested in the improving collaborative and cooperative learning in Alien Rescue. I find this topic especially interesting as collaboration will involve intricate social interactions and group dynamics.

It may be hard to have design or pedagogical elements that will ‘concretely’ foster collaboration and cooperation. Yet, reviewing the literature, I feel, will help me suggest methodologies that will help make significant progress in the right direction. So, in the next chapter, I review the literature on collaboration in PBL environments. In a later chapter, I also make suggestions to incorporate collaborative techniques in Alien Rescue.

## Chapter 3

### A Literature Review of strategies to increase collaboration in PBL environments

Given the findings in the previous chapter, I decided to focus specifically on collaboration in PBL environments while conducting the literature review. I first started my search in a broad manner. I searched for a combination of a few terms like ‘collaboration’, ‘problem-based learning’, ‘game’, etc. After that, I could significantly narrow down my search terms and the databases that I wanted to look into. I will first describe my findings from my broad, general review. Then, I will describe the more focused literature review.

For a pedagogical strategy to be successful, it is important to take into account students’ perspectives. This is especially important for non-traditional methodologies that involve some form of group dynamics (H. D. Johnson & Dasgupta, 2005). Chang (2009) said that role-playing creates good social interaction not just between students themselves but also between students and teachers. He also believed that this related to Vygotsky’s theories and social constructivism. His classroom experiment that involved role-play in a PBL environment found that most students responded positively to the instructional strategy. Similarly, Chan (2012) also found that nursing students had a positive outlook on role-playing in PBL. Furthermore, she also found that role-playing increased active and experiential learning. It also lead to teamwork, critical thinking, and creativity.

A recent study by Almajed, Skinner, Peterson, and Winning (2016) that looked into dentistry undergraduate student perspectives on collaborative learning had some interesting findings. They found seven things that positively affected student perspectives on collaborative learning. These were: (1) Coherence towards learning (2) Preparedness (3) Relaxed environment (4) Relevant topics (5) Tutor support (6) Individual accountability within a group (7) Good group organization. In particular, students liked that the interactions fostered sharing of ideas, questioning, ex-

plaining, confirming or challenging each others' knowledge. Apart from this, unequal workload, difficult personalities, limited participation, competition, etc, negatively influenced the students' experience. Clearly, group dynamics and social interaction seem utmost important for both successful cooperation and collaboration. Overall, it seems as though principles of social constructivism will apply to a collaborative learning environment. I have used this as a rough guideline while distilling themes from my literature survey.

After the broad literature survey, I decided to focus primarily on role-playing as a way to increase collaboration. This is partially because I saw many instances where student identity and 'role' were important for group work (Almajed et al., 2016; Chan, 2012). In addition, students using Alien Rescue already assume a 'character role' of a scientist, thus marking the importance of role-playing in the context of AR. After going through several different keywords, I narrowed down on the following keyword search- ('problem solving' OR 'problem based') AND (collaboration OR 'collaborative learning' OR 'group work' OR 'cooperative learning') AND (game OR gaming) AND ('role-play\*' OR roleplay\*). I used multiple words to describe collaboration, group work, cooperation, etc, to cast a wider net when searching for articles. In addition, using '\*' at the end of role-playing ensured that I could find all 'endings' role-play could have, such as role-play, role-player, role-playing, role-played, etc. Also, note that a hyphen and space character are counted as the same character in such a search, so both 'role-play' and 'role play' would produce the same results. To account for no space between role-play, I used 'roleplay' as an extra phrase. Finally, I used a simpler phrase, 'game', instead of 'online game' or 'serious game'. This too was to cast a wider net during literature search. I used the following databases to conduct my literature review.

- Education Source
- PsycInfo
- ERIC

These databases primarily covered educational journals. Although PBL has medical origins, I deliberately chose education journals as my primary reference sources. This was because methodologies applied to K-16 education would be more applicable to Alien Rescue. I searched for from literature after the year 2000 and in peer-reviewed journal articles, conference papers, and reports only.

The initial search yielded 26 results after removing duplicates. But, some conference papers were irrelevant to the topic. Some books were also somehow included in the search. After I removed these results, there were 22 results left. After reading these, I could extract some recurring themes. These themes are described in the next few sections. Also, I found that each every paper fell under at least one theme. A few papers fell under multiple themes.

### **3.1 Pedagogical strategies and themes for collaboration**

I observed four main themes that emerged from the literature review. These themes have to do with how the group of students is structured, the role the teacher has, and so on. These themes are described below. The first two focus primarily on students' individual and group role/identity. The next two themes are support mechanisms for the first two themes. I took special note of strategies that are socio-constructive in nature for all four themes.

#### **1. Specific group roles and identities based on personality traits:**

Sancho, Moreno-Ger, Fuentes-Fernandez, and Fernandez-Manjon (2009) used a highly complex socio-constructive framework called NUCLEO to foster collaboration. In this framework, three or four students grouped together to solve a problem or project at hand. The students were assigned roles based on their personality. For instance, students who were 'meaning directed' or 'application directed' were made captains. Students who were 'reproduction directed' were made 'knowledge integrators'. Finally, students who were 'undirected' were made communicators. Students are given access to tools based on their role. Thus, team formation and role assignment are given the most importance. These teams are inter-dependent based on role and expertise of each student. In a survey, most students reported that they found the role assignment and team formation to be useful. I would, however, like to point out some areas of concern. These are: (1) Meaning directed and application directed students performed better than other students. Although this was expected by the researchers, perhaps something could have been done to alleviate the situation. (2) Some students felt uncomfortable if they were paired with completely new people. (3) Some students felt that only the role of the captain was useful and others were secondary. (4) NUCLEO relies on 'learning preferences' to divide students into groups. The use of 'learning preferences' may be questioned by

many researchers.

There were several other studies in which students were assigned specific roles. Melissourgos, Paraskeva, and Mysirlaki (2015) had team formations to solve problems in a Massive Multiplayer Online Role Playing Gaming (MMORPG) environment in a middle school setting. They suggested that the number of players in the group should be four. The roles assigned were the team leader, scout, and two councilors. Log data showed that there was bullying reduction, maintenance of excitement and concentration throughout the game. Ianes (2006) also suggested assigning different roles to students with special needs in cooperative learning scenarios. These roles included explorer, strategist, critic and sage. Apart from this, Cai Klein-Seetharaman (2005) and Wall and Morgan (2015) also had ‘division’ of roles in as the pedagogical strategy in their experiments.

In a similar, yet different, manner Yan et al. (2013) proposed to assign roles to students in collaborative, immersive, virtual environments based on their individual learning goals. They also wished to support individualized learning with ‘intelligent’ tutoring system. This presents at least two important aspects of role assignment. (1) Learning goals could be used to assign students roles instead of ‘learning style’. (2) Even if it is a collaborative or cooperative environment, it is important to support students’ individual learning needs and goals.

Tan, Jan, and Tan (2013) observed something interesting when they assigned specific roles to people. Due to the role-based division of labor, the students formed ‘role-identities’. The role identities were reflexive and had three aspects associated with them: agency, social and ideology. McCreery, Schrader, and Krach (2011) found evidence that ‘novices’ have a lower socio-spatial interactivity than ‘experts’. In some cases, this could be countered if there is an ‘exchange of expertise’ while forming groups (Siyahhan, Barab, & Downton, 2010).

## **2. Assuming specific avatar, character or ‘self’ roles:**

In some online games, students assumed the roles of ‘themselves’. In some other games, they assumed the roles of a fictional avatar. Both of these have potential positive aspects.

Lynch, Mallon, and Connolly (2014) described ‘Plunkett’s Pages’, a



serious alternative reality game (ARG), where students play as themselves. According to them, in general, ARG lead to agency, collaboration, and strong community bonds. In addition, serious ARG encouraged deep learning and interdisciplinary media inquiry. The students also appreciated their teammates as they played the game. But, students playing ‘themselves’, the researchers postulated, would lead to “This Is Not A Game – TINAG” mentality. This, they felt, would help students connect to the game better. They proved this to be true in the context of their game. Of course, there may be some negative ramifications if fact and reality blur. The researchers also addressed this fact and that is explained in the next theme.

In a different perspective, Voulgari and Komis (2010) noticed that students really liked creating virtual avatars in massively multiplayer online games (MMOGs) such as *Lineage II* and *World of Warcraft*. In fact, they became very attached to their virtual characters as they had spent time customizing them, selecting appearance, skills, etc. They felt pride as their characters, as it was almost like their ‘child’, their creation. One student reported that he would feel sad if there were no characters to customize, as the ‘society’ will become boring and uniform. Thus, we see implications of the socio-constructivist view once again. ‘Societal identity’ seems to affect people as much as ‘individual’ identity. Edmunds and Wall (2009) developed a problem-solving methodology called ‘MGD Explorers’. This methodology was supposed to teach students to address issues of global poverty. Students assumed a fictitious role of a person from a certain country and with a certain income level. Teachers noticed this about the students- “The teachers disappear into the landscape while the students assume responsibility for their collective learning. Together they face challenges, collaborate, listen and problem-solve if their existence depended on it” (p. 80). Yet again, we see how group dynamics are essential for students. It does not matter if their character roles are fictitious or not.

### **3. Briefing and debriefing as a part of gameplay:**

Briefing can be classified as discussions the teacher(s) and students have before they start their game or activity. Debriefing can be classified as discussions and reflections on learning after the activity or game is played. As mentioned earlier, Lynch et al. (2014) addressed the fact that “TINAG” was experienced by their students. To combat this, the teachers ensured that they

emphasized the differences of fact from reality during debriefing. The students also reportedly appreciated this fact.

Several other researchers employed this methodology. For instance, Wall and Morgan (2015) had both small group and large group debriefing sessions to reflect on learning. Tan et al. (2013) also had it embedded into the entire gameplay arc.

Sometimes, novices may require more guidance than experts in a gaming environment (Al-Washmi, Hopkins, & Blanchfield, 2013; McCreery, 2011). If they do not have the required amount of support, they may not utilize the game to the full extent. Teachers can help introduce concepts and facilitate setting goals during the briefing sessions, depending on individual needs.

#### 4. **The teacher role:**

The earlier sections explain the importance of teachers as facilitators, especially during briefing and debriefing sessions. In particular, Mukhamedyarova and Cotter (2005) cited the importance of having a teacher as someone who facilitated and structured collaboration and role-plays.

Apart from the role of a facilitator, there is another important aspect relating to teachers- teacher education. Yu (2009) advocated that pre-service teacher education programs need changes. He wanted these programs to include technology, gaming, and virtual worlds in education. Later, Schrader, Archambault, and Oh-Young (2011) trained pre-service teachers to use Massively Multiplayer Online Games (MMOGs) in their classrooms. They found that, in general, teachers perceived games to have a high curricular cost with low educational returns prior to their training. The teachers who received their training could appreciate the educational affordances of MMOGs. They proposed that future pre-service teacher education programs should have examples of gaming as an educational tool. Only then can the use of games in classroom teaching become routine.

### 3.2 **Design strategies and themes for collaboration**

Most of the research articles and reports focused on the pedagogical aspects of fostering collaboration. There was, however, one article that focused primarily on the design of collaborative tools. Bodin, Marty, and Carron (2011) developed a collaborative game called '*Learning Adventure*' with several tools aimed primarily at

collaboration. *Learning Adventure* was a virtual environment where students could walk around as avatars, explore, interact, etc, while performing the required activities. The researchers incorporated three main collaborative tools in the environment.

1. The chat tool: Students used this to communicate with other players (students) at any point of the game.
2. The ‘post-it’ wall: This wall space acted as a ‘meeting’ space for the students. Each student could pin a post-it to the wall. Each student could also move any of the pinned post-its around. Every student had the same view of the wall. Thus, this was mostly used by students to organize ideas as a group. Teachers could observe the data of student interactions with a ‘pie-chart indicator’.
3. The ‘collaborative feather’: This tool provided students the opportunity to co-edit documents. In some ways, it was like Google Docs. But, it also had features that differentiated it from Google Docs. Each student had a personal space in which only she or he could work. Then, there was a collaborative space where students can post ideas. Only the ideas will be visible on the board. But, each student could write positive or critical color-coded comments for an idea, which would be visible if a student clicks on the idea. Lastly, there was a ‘marble space’ where ideas approved by the whole group could be ‘engraved’. Teachers could observe the data of student interactions with a ‘pie-chart indicator’.

These tools provide great examples of specific tools that can be incorporated in a learning environment. Most importantly, the data of student interacts was made available to teachers. This significantly helped teachers see the areas where students had trouble collaborating.

## Chapter 4

### **Design and pedagogical suggestions to increase collaboration in Alien Rescue**

Given the literature reviewed, in this chapter I outline the suggestions to increase collaboration in Alien Rescue. Although I simply say ‘collaboration’, I also intend it to have ‘cooperative’ elements. First, I will describe the overall changes that can be made to Alien Rescue, as I envision them. Later, I will write the pedagogical and design strategies that I think will support this change.

Alien Rescue enables students to role-play as scientists. To encourage collaboration, I feel students could be divided into groups of four. Furthermore, I wish to assign students specific roles, even as they think of themselves as a ‘scientist’. I feel that within each group, students could have the following roles: (1) Lead scientist (2) Research Specialist (two students) (3) Scientific communication specialist. My reason for choosing these roles is that it is reflective of the NUCLEO framework: (1) Group Lead (2) Knowledge integrators (3) Communicators. The description and flexibility of roles, however, are a little different

Each student will be able to do everything that Alien Rescue requires. They will not be stopped from doing an activity that another student role can do. But, they will be asked to focus the most on the role assigned to them. The lead scientists would be responsible for overall organization and management of the group. They would primarily be in charge of budget decisions, directing conversations, managing disagreements, etc. The research specialists would be primarily in charge of collecting data, sending probes to find missing data, etc, while listening to suggestions from other group members. The scientific communication specialists would primarily be in charge of presenting the groups’ final case/hypothesis for assigning a home to a certain alien. They would also be responsible for communicating with other small groups and with the teacher(s). Creating an environment of social interdependence may encourage students to work with each other instead of just requesting for help

or telling other students the answers directly.

These roles can be initially assigned depending on the teachers' intuition and what they feel might align with students' needs. But, these roles can later be reassigned. As Tan et al. (2013) observed, students assume 'role-identities' based on what roles they are assigned. Thus, even if assigned a different role after some time, the students might not have too much problem slipping into it. Perhaps each group could play the initially assigned roles until they find a suitable home for two alien species. Later, for the next two species, they can be reassigned. Finally, for the last two species, they can be reassigned again. In this way, each student plays each of the three different roles that are present. The following pedagogical and design strategies might help sustain such a technique.

#### 4.1 Pedagogical suggestions

Before the students start the game, the teachers must get comfortable with the game. Currently, Alien Rescue enables this by providing a 'Teacher Portal'. This portal has lesson plans, instructions, screencasts of the game, etc. In addition to this training, I propose that teachers actually play the game. In this case, I would want the teachers to play exactly how the students would be expected to play. Thus, they could partner up with other teachers, friends, or student designers in Alien Rescue to play the game in groups of four. As Schrader et al. (2011) suggested, this would positively impact teachers' perceptions of a learning environment

Requesting teachers to play the game may also motivate potential new teachers. As Schrader et al. (2011) and Yu (2009) both said, introduction to the game by actually playing the game may inspire more teachers to use a certain learning environment.

During the 'briefing' procedure that addresses the entire classroom, I suggest that teachers could describe roles, goals, and general guidelines to students. They could also ensure they give special focus to novices, as recommended by McCreery et al. (2011). They should continue to give examples of famous scientists and their collaboration techniques, as suggested in the teacher lesson plan.

After the 'larger' group session is over, the students could meet up for a 'small' briefing session within their assigned group. They should be encouraged to meet regularly with this group.

During the game, teachers could make a note of instances of student inter-

action and collaboration. If they feel they need to intervene, they should step in. Else, teachers could ‘melt’ into the background, as it has often been found useful (Edmunds & Wall, 2009). Currently, Alien Rescue is being prepped so that teachers can view student activity and progress on a ‘teacher dashboard’. If design permits, in later versions, teachers would hopefully be able to unobtrusively see instances of student interactions on their dashboards.

After the Alien Rescue session is over completely, there should be a debriefing session. During this, teachers could encourage students to reflect on their learning. In addition, teachers could mention the significance of each role and why each role is a crucial part of a group. This might ensure that students do not think only the ‘leader’ is the most important role (Sancho et al., 2009).

## 4.2 Design suggestions

Some form of customization may make students feel more connected to their specialist roles within an environment (Voulgari & Komis, 2010). For instance, even a simple line that says ‘Research Specialist’ on the top of their screen might add a value of individual identity. As mentioned in earlier sections, having this ‘individual accountability’ in a collaborative environment would make it ‘cooperative’

Depending on the role that a student is playing, some cognitive tools can be customized. For instance, each role can have a dashboard that provides them with some extra information that the other roles may not have. In addition, the dashboard can provide the significance and importance of each role. This too may help students recognize the importance of each role and that all are equally essential. In the end, they can receive a summary of each role they played. Due to such an arrangement, students might recognize their interdependence and hence wish to collaborate and cooperate.

In addition, the notebook tool in Alien Rescue could possibly be made more collaborative. Perhaps it could have a personal space and collaborative space, as in ‘Learning Adventure’ (Bodin et al., 2011). The ‘research specialists’ may want to draw from other peoples’ notes to make connections to fill in the gaps between existing data and data from probes. In turn, the other members may review and constructively critique the suggested connections. This means, even if some students have a ‘sick day’, they would still be able to play remotely and communicate with their group.

### 4.3 Implementation and Evaluation

I made many suggestions in the previous sections. In this section, I suggest some ways to implement the changes. I also suggest ways that can be used to measure the effectiveness of the changes. These are especially critical, as they will validate the usefulness of my suggestions.

Any change is difficult to implement. Changes that involve large groups of people, especially students who are learning at school, will need very careful planning. This is a big reason why Alien Rescue undergoes many rounds of testing before a new version is released for students to use. The research group wants to ensure that a new version does not affect the learning of students. Keeping this in mind, I suggest the following strategies for **implementing** this change.

First, conducting a pilot test with graduate student volunteers will be useful. Half of them could be put into groups of four and assigned specific roles. (At this stage, there will not be any design customization for the roles in the learning environment). The other half could be encouraged to collaborate as well, but they would not have specific roles. Comparing the test performance, instances of interaction, user perceptions, etc, will give important insights into the validity of creating groups.

If the role assignment strategy is deemed successful, the AR team could proceed with prototyping with the ‘design’ changes in Alien Rescue on a simple app. At this stage, one probably should prototype only the ‘customized’ features (eg: A line that says ‘Research Specialist’ on top), and not complicated elements like the collaborative notebook. Then, the team could conduct the pilot test again with the same graduate students. They would be using the prototype design model this time in conjunction with the actual learning environment. Finally, they can conduct a cognitive walkthrough and evaluation of the prototype.

If proved useful, the team can implement it in the actual learning environment. They can set up the system so that certain pages can be toggled on or off back-end depending on the role of the student. If all of these elements work fine, they can consider making a collaborative notebook. To test this, they could have a few students act as participants for a pilot study. They should have them use Google Docs as a ‘collaborative’ space and the ‘notebook’ as a personal space. Then, they can see how the group dynamics are affected due to this tool.

If the tool seems to be useful, they can consider building it in the learning

environment itself. The environment would then be ready to undergo overall testing. If required, the team can do another small pilot with younger kids.

If such a version is built, we need to ensure it is effective. Given below are strategies I suggest for **evaluating** this new version during the building and piloting process. I also suggest using the evaluation techniques in schools after the version is built (after pilot testing).

The teachers and the AR team can ensure that the students take the science knowledge tests, especially during the pilot study. They can also request students to respond to a questionnaire that asks them the effectiveness of group formation and importance of each role (Sancho et al., 2009).

In addition, conducting qualitative observations of interactions between students would be useful. Also, conducting qualitative interviews of a few students after they finish playing Alien Rescue would be great.

For a more quantitative approach, the AR team can use the Baker-Rodrigo Observation Method Protocol (BROMP) (Ocumpaugh, Baker, & Rodrigo, 2012). BROMP is a software that will enable a person to record observable behaviors of students (This data is recorded into categories such as ‘on-task, talking’, ‘off-task, looking away’, and so on). This data will have timestamps and can later be matched with the log data of students to give an overall view of engagement, boredom or other behaviors. This will enable individual insights into students’ behavior and affect. In addition, the collaborative effort along with the individual effort of the students can also be known, as ‘on-task, talking’ behaviors can be combined with the timestamp data. This will be especially useful to gauge student participation in a group as well as individually. Often, teachers are unable to assess both these characteristics individually and in combination with just traditional tools.

Thus, hopefully, these implementation and evaluation strategies will be useful for the creation of the next version of Alien Rescue.

#### **4.4 Limitations**

The strategies suggested in this report cater specifically to Alien Rescue. In particular, the design and implementation strategies are exclusively for Alien Rescue. Perhaps some suggestions could be extended to other PBL platforms as well. But overall, the approaches suggested here reduce the generalizability of this report. Nevertheless, one could spend some time to modify suggestions so that they can



incorporate these strategies to their specific contexts.

#### **4.5 Conclusions and Implications**

In this report, I reviewed the literature to find strategies that foster collaboration in PBL environments. Using the findings, I then suggested strategies that can be used specifically in Alien Rescue. I also suggested ways to implement the strategies and evaluate the effectiveness.

Since Alien Rescue has a unique and iterative research and development process, I feel that these suggestions will be useful to the Alien Rescue R&D team. If found effective in Alien Rescue, perhaps these methodologies could also be contextualized to other PBL environments. This would be especially important, as group work is an increasingly important skill that the current generation of kids need to know.

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## Vita

Sukanya Kannan Moudgalya was born in Mumbai, India. She did her Bachelor's in Industrial Biotechnology in India as well. In the fall of 2015, she joined the department of Curriculum and Instruction, with a focus on Learning Technologies, at the University of Texas at Austin.

Permanent email: [sukanya.moudgalya@gmail.com](mailto:sukanya.moudgalya@gmail.com)

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