HE, RUICEN

TOWARD A CONSTRUCTIVE PERCEPTION OF FAILURE: A COMPARISON OF GROUPS IN A FACE-TO-FACE COLLABORATION CASE

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Abstract

Minor or big, permanent or temporary, failure is widely experienced by people of different nationalities, ages, social status, and genders, at any stages of life, in a tremendous scale of day-to-day situations. A common misunderstanding and underestimation of failure as a state of negative result is that failure of performance indicates failure in learning and knowledge building, and that it is bad and disadvantageous. Though failure is usually believed to be a negative and disappointing result, it to some extent plays an important and positive role in our lives, and many people learn from their previous failures and failures of others. In the field of education, the role of failure in facilitating and enhancing learning has been studied in literature for years.

This research mainly serves to explore how learners collaborated, performed and learned, and how exactly learners in collaboration learn from failure in their learning. To support my research, the literature review starts with the differences of learning and performance, then it comes to the definition and perception of learning in general. After this section, definition of collaboration and characteristics of collaborative learning are introduced. Later, after the sections on performance and learning, comes the sections in which various possibilities and mechanisms of failure-enhanced learning are introduced and discussed.

The data were collected from a video-recorded research session designed and carried out by the PROMO research team from a university located in a Nordic country. Participants were twelve first year and second year international Master’s degree students (seven female, five male) in the field of education. The twelve participants spontaneously formed three groups of four, all groups then were assigned the same open-ended problem-solving task, which required each group to work on a three-hour-long epistemic game in three separate rooms.

The result of my research suggests that, firstly, poor or good performance does not always indicate the failure or success in learning, a full picture of both the process and results can offer a more complete understanding of how learners learned. For example, it is possible that a group with satisfactory academic performance or final presentation may actually have poor learning, while a lower-performing group may experience better learning though they had poorer performance or final presentation. The next finding is that students could learn from challenges or failures, but those who are more aware of the challenges, and faced the challenges with more positive emotions and good problem-solving strategies could learn more from failure and the process of finding proper solutions to the challenges, and are more possible to tackle challenges and thus avoid them accelerating into failures.

Keywords | learning, collaborative learning, performance, failure, learn from failure
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1 INTRODUCTION

Minor or big, permanent or temporary, failure is widely experienced by people of different nationalities, ages, social status, and genders, at any stages of life, in a tremendous scale of day-to-day situations. In school years, people as students particularly experience failures in their learning, mostly in exercises, diagnostic tests or periodical exams. Also in other stages of life, people experience errors, mistakes, failures and near-failure situations.

A common misunderstanding and underestimation of failure as a state of negative result is that failure of performance indicates failure in learning and knowledge building, and that it is bad, disadvantageous, or malign (Gartmeier, M., Bauer, J., Gruber, H., & Heid, H., 2008). A negative viewpoint on failure can also be very problematic. Because from a psychological point of view, the interpretation of failure is more important than failure itself (Georgiou, S. N., Christou, C., Stavrinides, P., & Panaoura, G., 2002). This echoes with my personal experience as a student for nearly two decades: so often, it was not failure itself, but the negative emotions of students emerged from teachers’ and parents’ negative attitude toward low-achieving students that was making students academically unmotivated, or students simply see previous failures as settled results so no attention will be given to those failures, nor any learning from failure would emerge. Also, a hidden danger is that a simple “pass or fail” judgment does not only frustrate poorer-performing students, but can also make better-performing students overly confident, as a result, the assessment fails to serve its aim to improve learning. Thus I am confident that a more positive view on failure as a chance to learn is more beneficial than a negative view.

Learning from failure is not a new idea. An ancient Chinese idiom says that failure is the mother of success (失败乃成功之母). Though failure is usually believed to be a negative and disappointing result, it to some extent plays an important and positive role in our lives, and many people learn from their previous failures. In field of education, the role of failure in facilitating and enhancing learning has been studied in literature for years, producing theories such as Productive Failure (Kapur, 2008; Kapur &
Bielaczyc, 2012; Kapur & Rummel, 2012; Kapur, 2014, Vicarious Failure (VF), Negative Knowledge (Gartmeier et al., 2008) and Impasse-driven Learning (Vanlehn, 1988); yet the constructive and positive role of failure in learning, knowledge building and problem-solving does not receive the emphasis and understanding as it deserves and remains largely underestimated and under-researched. (Kapur and Bielaczyc, 2012, pp. 46).

In educational context, if failure is going to be studied, we need to decide which to focus on: failure in learning or failure in performance, from which I choose to focus on failure, because instead of performance, learning is the key of education. One of the key points that has been overlooked is the fact that performance and learning are distinct and different to each other. And the garble of performance and learning has led to many misunderstandings.

To clear up the myths of why learning and performance are different and that the reliance of performance as an indicator of learning is problematic, Kapur (2008) concluded that firstly, we need to understand that firstly, our reliance on performance as an indicator of learning, in other words, is our reliance of the observation and measures resulting in performance. The logic beneath is that we say the success or failure judged by measures is called performance, which is often believed to indicate learning. The logic obviously does not work as what we take for granted (Kapur, 2008). Then secondly, to support the first statement, measures and observations has their limitations, for example the validity, scope and time duration of an assessment method of learning, for example examinations. And learners being assessed by those measures cannot break free from the limitations (Kapur, 2008).

Limitations of assessment methods can be of various reasons, some concerns the design features of assessment methods, and some concerns the designers of assessments, for example teachers, who also has their own limitations of capabilities and abilities. Finally, back to the assessed learners, it is reasonable to argue that their ability to explore and find solutions to a problem in an assessment session
can be restricted by many factors, for example the assessment tools being used, teaching methods of their teachers, their own thinking patterns, self-esteem and time-managing skills.

My studies presented in this thesis is of academic importance and it is significant to my personal knowledge building and self-development. In general, my thesis is written in a descriptive and narrative tone, by which I am trying to be as objective and unbiased as possible, bearing in mind that I have limitations; meanwhile especially in the literature review I tried to collect previous literature which are both suitable and significant to support my studies. Also, I started with the belief that only to know better about learning itself, could educators and also other participants in education develop themselves.

One of the most important implications and also what motivated me to conduct this research is to spread a constructive attitude toward failures and mistakes, thus failures and mistakes are taken the most advantage of, and thus future and even worse mistakes or failures could be avoided or weakened. This could be applied not only to students in school years, nor limited to individual persons, but could also be practical and beneficial to a larger scale: a country or a society.
2 LITERATURE REVIEW

Before trying to understand and explore the connection of learning, performance and failure in educational settings, breaking the concepts apart and understanding them individually could provide a solid foundation to the construction of the road leading to the core topic: the positive and constructive role of failure in learning. A literature review based on the existing works of related issues offers strong theoretical support to the further development of my research and arguments.

Firstly, since the discussion starts with failure in learning and learning from failure, the best starting point could be defining learning. However, before it comes to the definition of learning, there is a mist to be cleared: the difference of learning and performance. After making clear the differences of the two concepts comes the definition of learning, and especially the definition of collaborative learning (Weinberger, 2014; O’Donnell & Hmelo-Silver, 2013) and characteristics of effective collaborative learning (O’Donnell & Hmelo-Silver, 2013; Johnson D.W. & Johnson R. T., 1987; Johnson, D. W., Johnson, R. T., & Smith, 1989; Vuopala, 2013). Structuring and scripting collaborative learning (Vuopala, Hyvönen & Eagle, 2014; Dillenbourg, 2002; Dillenbourg, 1999; O’Donnell & Dansereau, 1992; Kollar, Fischer & Slotta, 2007; Kollar, Fischer & Hesse, 2006; Kobbe, Weinberger, Dillenbourg, Harrer, Härmäläinen, Häkkinen & Fischer, 2007; Diziol, Walker, Rummel & Koedinger, 2010; Weinberger, Kollar, Dimitriadis, Mäkitalo-Siegl & Fischer, 2009; Dillenbourg, 2002) puts an end to this section.

Then after understanding learning, comes the “learning from failure” part. This part starts from understanding negative knowledge (Gartmeier et al., 2008) or knowing what NOT to do as one of the important things we learn from failure. Then from the lenses of 21st Century Skills (Dede, 2010; Binkley, Erstad, Herman, Raizen, Ripley, Miller-Ricci & Rumble, 2012), learning from failure is believed to be an important skill that benefit in a long run. The theoretic fruits included in this part such as impasse driven learning (Vanlehn 1988; Brown & Vanlehn, 1980), productive failure (Kapur, 2008; Kapur & Bielaczyc,
2012; Kapur & Rummel, 2012; Kapur, 2014) and vicarious failure (Bandura, 1971; Kim & Miner, 2007; Kapur, 2014) would brief us of some insights into how exactly learning from failure could work.

2.1 Learning and performance

Without really thinking about it, so often we take it for granted that learning and performance are considered twins, and it sounds like a paradox to distinguish learning and performance. I am not the first one nor the only one that noticed this gap between the identification or conceptions of learning and performance. My thinking echoes with statements found in works of researchers such as Kapur (2008), E. L. Bjork and R. A. Bjork (2011).

To clear up the myths of why learning and performance are different and that the reliance of performance as an indicator of learning is problematic, Kapur (2008) concluded that firstly, we need to understand that firstly, our reliance on performance as an indicator of learning, in other words, is our reliance of the observation and measures resulting in performance. The logic beneath is that we say the success or failure judged by measures is called performance, which is often believed to indicate learning. The logic obviously does not work as what we take for granted (Kapur, 2008). Then secondly, to support the first statement, measures and observations has their limitations, for example the validity, scope and time duration of an assessment method of learning, for example examinations. And learners being assessed by those measures cannot break free from the limitations (Kapur, 2008).

Though learning and performance are different, the relation between them does exist, just as what we expected. Students’ understanding and conceptions of learning are proved by researchers to influence their learning approaches and learning outcomes (Chaleta, Gracio, & Ramalho, 2012). And learning outcomes can be measured, however not completely indicated by assessment, resulting in performance.

Learning without performance and performance without learning are two situations in extreme cases. In their work Making Things Hard on Yourself, But in a Good Way: Creating Desirable Difficulties to Enhance Learning, Bjork and Bjork (2011) alarmed us the danger of learning without
performance and performance without learning. Learning without performance and performance without learning, though impossible they appear to be and obviously unwanted, can actually exist. In other words, it is probable that learning takes place when no obvious performance can be seen or conversely, satisfactory performance can exist without significant learning. As a consequence, people trusting performance as the assessment of learning can be misled to overlook whether, exactly did learning occurred (Bjork and Bjork, 2011).

2.2 Defining learning

Then after the mist of the differences between learning and performance is cleared, comes the definition of learning, though learning as a basic vocabulary and concept, is often taken for granted. Without the help of dictionaries or other references we can hardly come up with a proper and decent definition. It can also be explained and paraphrased in different discipline and context. In Merriam-Webster dictionary online, learning as a noun is described as “the activity or process of gaining knowledge or skill by studying, practicing, being taught, or experiencing something” (2015). In literature, learning is defined in different words. Learning can be seen as a combination of knowledge communication process and knowledge compilation process (Vanlehn, 1988; Anderson, 1985). According to the explanation of Vanlehn (1988), during knowledge communication process, students extract knowledge from instructions and the environment and turn the extraction into their mental structures. Then after this process, the initial mental structures are transformed during the knowledge compilation process by means of practicing, in return, the transformed mental structure becomes less likely to be forgotten and improves the speed and quality of performance (Vanlehn, 1988). Similar but clearly different, Kapur (2014) concluded that learning is part of the function, where students are able to see the similarities and differences between their prior knowledge and target knowledge (Kapur, 2014; Lehtinen & Hannula, 2006).
And there is more to know to understand learning: Chaleta, Gracio, and Ramalho (2012, pp.6) concluded the identified sixteen conceptions of learning from previous researches and studies:

1) Increasing of knowledge;
2) Memorizing;
3) Applying;
4) Understanding;
5) Seeing something in a different way;
6) Change as a person;
7) Personal fulfillment;
8) A duty;
9) A process not bound by time or context;
10) Broad and diversified;
11) Developing social competence;
12) Interactive and social process;
13) Teaching process;
14) Individual and individualized process;
15) Experiential process;
16) As a value.

(Chaleta, et al., 2012, pp.6)

These definitions and conceptions of learning offered new thinking on learning. Learning is not as easy and simple as an “input-storage-output” process, in which we assume that all students have a built-in
learning ability, instead, learning is a process which has a completed mental and cognition structure, which requires students to have great meta-cognitive skills, which also should be developed with the assistance of peers, educators and parents: learning requires both social interactions and personal patterns unique and diverse to the individual learners. Most importantly, learning as a process requires a gradual, intertwined yet well-organized functioning of psychological and cognitive progress at different phases. This also echoes with Winne’s (2011) understanding of learning, in which knowledge plays a key role. Knowledge as one of the three inputs to learning “provides inputs to various cognitive operations and meta-cognitive operations”, and that “knowledge plays roles in transforming experience into information and information into knowledge”. Along with knowledge, information and experience together makes the three types of inputs to learning (Winne, 2011, pp.15-16).

2.2.1 Understanding collaborative learning

Learning comes in various forms in different contexts. One of the most seen types of learning is peer learning. Under this umbrella term, we can find three types of learning: peer tutoring, cooperative learning, and collaborative learning (O’Donnell & Hmelo-Silver, 2013). All these three concepts are widely practiced and researched, and there are different criteria to distinguish them from each other.

Though sounded and looked alike, collaborative learning and cooperative learning are two different types of peer learning. Instead of listing below definition of these two concepts, knowing about the similarities and differences will help to eliminate confuses and have a deeper understanding of those two types of “learning together” methods. In one of his video lectures, Weinberger (2014) introduces a method to distinguish cooperative learning from collaborative learning based on the presence or absence of sub-tasks. According to Weinberger (2014), when learning cooperatively, learners split the learning task into smaller sub-tasks, and in the end, they add up those sub-tasks and construct a final output. In collaborative learning cases, there is no deconstruction of the central task as in cooperative learning. Instead, different learners concentrate on the same task at the same time, producing together the final
outcome. Likewise, O’Donnell and Hmelo-Silver (2013) refer to equality and mutuality as two criteria of collaborative learning. In peer tutoring situations, there are tutor(s) and tutee(s), tutors serve as help providers and tutees as receivers, their roles are unequal. Their interaction and flow of knowledge is one-directional. When people learn together in groups, here, we mean cooperative and collaborative learning, participants are supposed to be equal in status and contribution. The difference is that, the distribution of work in cooperative learning is every individual learner is responsible of working in a certain sub-task and that during the working process, learners quite often do not need to exchange their ideas or knowledge. While if a group is learning together collaboratively, it means that all participants are working on the same task, which will not be divided into independent sub-tasks. So we come into a conclusion that peer tutoring is low in both equality and mutuality; cooperative learning is low in mutuality but high in equality, and collaborative learning is high in both equality and mutuality (O’Donnell & Hmelo-Silver, 2013). However different they are, or even it seems that collaborative learning is the “best” peer learning method. It is not the truth. Being different is just being different, all types of learning methods, if used right, can be beneficial in promoting learning and other related skills.

2.2.2 Characteristics of effective collaborative learning

Collaborative learning can happen in both physical and virtual contexts or combined, for example traditionally, students learn collaboratively in a face-to-face situation, or with the help of ICT technology, learners are able to work collaboratively using technology. Even though collaborative learning comes in various types, and that many factors contribute to the practice, the key characteristics of successful collaborative learning are similar, no matter what contexts learners are in.

Again, it was O’Donnell and Hmelo-Silver (2013, pp. 4) that introduced the five characteristics of effective collaboration. I read about these characteristics before, and actually included this into a collaborative group work (Enckell, He, et al., 2013, section 2.2 “The Five Characteristics of Collaborative learning”):
Positive interdependence

Interdependence means that all the participants in a group are dependent upon each other when working on the task. Positive interdependence is that if an individual learner in a group wants to succeed in the task, all the other individual in the group and also, the whole group need to be successful as well. And vice versa, if a whole group want to succeed, every single individual need to succeed too. Negative interdependence in contrast is a competitive context, when one individual accomplishes his or her goals, other participants can’t do so. (O’Donnell & Hmelo-Silver, 2013, pp. 3). Negative is not something we want to see in an effective collaborative learning experience. To make it even easier to understand, an effective collaborative learning group “sink or swim together” (Johnson D. W. & Johnson R. T., 1988, pp. 34).

Face-to-face promotive interaction

In a successful and effective collaborative learning session, face-to-face promotive interaction can be experienced and observed if applicable. When there is F2F promotive interaction in a group, members are promoting each other’s cognitive skills. Learning together and interact with others, learners experience different format of information processing, cognitive load, meta-cognition, and knowledge building than if they learn individually. The free flow of exchanging ideas, group pressure and feedback from peers are playing a rather positive role in deepening understanding, staying on task and improve their individual section (O’Donnell & Hmelo-Silver, 2013, pp. 4-6).

A healthy collaborative learning case asks from students’ great respect and interaction among each other. Working together can not only help enhance students’ social skills, but also has the possibility to bring students social and emotional support, such as confirmation, acceptance, which they need from their peers. It also helps with students to have a higher satisfaction with school and have a positive view on academic performance and competence (O’Donnell & Hmelo-Silver, 2013, pp. 3).

Individual accountability
Individual accountability means that each group member is responsible for his or her performance (O’Donnell & Hmelo-Silver 2013, pp. 4). And that individuals in a group are trying their best to contribute to the group work, and that they are eager to increase their accountability by developing their personal capabilities. It helps to ensure equal participation in collaboration, thus, it proposes to be a promising and practical solution to prevent the free rider effect, which means that some group members only do little work or simply nothing even they are expected to work within a group.

*Interpersonal and small group skills*

To practice an effective collaboration, good social and interpersonal skills are required, especially when it comes to working and communicating well with other group members. Of equal importance, small group skills are also required. It is called “small” group skills because ideally, a successful collaborative group contains 4-5 members. If there are 8 or more than 8 members in a group, students will automatically split into smaller groups (Vuopala, 2013).

The formation of the group is a big challenge for the teacher or educator. How to allocate diverse students into groups? How big should a group be? Vuopala (2013) answered in these questions on her lecture. She confirmed that people from different backgrounds and interests provide different perspectives which are required in successful collaboration. But it is also important that group members manage to find a common ground. Not only group members need to learn to participate equally, but also, the learning task itself should support equal participation and contribution. Another important issue is that we want all group members to feel safe, secure and committed to the group, so that they can work with more positive emotions. Interestingly, Vuopala (2013) also stresses that a successful collaborative learning group have not only task-oriented communications, but also casual talks, which can be inner jokes, mutual background, everyday stories, complaints, etc. Though seems to be off-task, these casual communications help to build a culture in the group and enhance a safe and trustworthy environment, which in return, have the possibility to promote collaboration (Vuopala, 2013).
Group processing

Again, in her lecture, Vuopala (2013) summarized the phases of a group development based on the Tuckman (1965) Model of group development: forming (in this phase, the roles, the goals are yet unclear), storming (conflicts and arguments begin to occur), norming (how we work as a group, set goals, set down individual’s roles), performing (In this phase, all the preparation develop into real work). Groups who succeed in collaboration must work through the stages of forming, storming and norming, then finally reach the stage of performing, in which real working could be carried out.


In Figure 1 there are five stages, forming, storming, norming, performing and adjourning, of which the last one, adjourning was a later update to the model by Tuckman and Jensen in 1977. However, in my research I would like to stay with the original four-staged Tuckman Model with only forming, storming, norming and performing.
2.2.3 Structuring and scripting collaborative learning

Instructions of collaborative learning and learning in general come in large variants, for example scaffolding, scripting, peer guidance, etc.. On one hand, instructions provide guidance and assistance; on the other hand, instructions can restrain the degree of freedom and thinking of students in problem solving cases (Wood, Bruner & Ross, 1976; Kapur & Bielaczyc, 2012). Even though instruction can have some side effects, it is widely believed that students especially at early and basic levels need to be tightly structured because especially at this level, the pros of instructions outshine the cons.

Vuopala et al. (2014) argued that collaborative learning does not happen spontaneously, and it needs to be supported. Their arguments parallel with Dillenbourg’s (2002) belief that learning cannot be produced systematically by free collaboration; and that one of the ways to foster effective collaborative learning is to structure and regulate collaborative learning via well-designed scripts.

Collaborative scripts are widely used to structure and regulate collaborative learning. Just like scripts used in other contexts of education, a collaboration script is a set of instructions demonstrating what the students need to do to work collaboratively and how they can achieve effective collaborative learning, for example, a collaborative script gives instructions on how to form groups, how students should interact and collaborate and how they should solve the problem. To be more specific, a collaborative script may contain instructions on aspects for example task definition, group definition, distribution, mode of interaction, and timing (Dillenbourg, 2002; O'Donnell & Dansereau, 1992). And again, like other educational instructions, a collaborative script can be very flexible and can be modified and designed by the educator and comes in various models, forms, contents, scales and degrees of structuring depending on the content and context the learning activity is situated in.

External and internal scripts. There are many existing models of scripts educators can refer to, also, there are many ways to categorize scripts depending on what aspect you are looking at, for example, there are micro scripts and macro scripts, internal scripts and external scripts, adaptable scripts and
adaptive scripts with respect to their degree of granularity, the presence or absence of scripts in the learner’s cognitive system, or flexibility (Kollar et al., 2007; Kobbe et al., 2007; Diziol et al., 2010). Among them, internal scripts and external scripts, to some extent, are closely related to the research design of my research. According to Perkins (1993), the differences between external scripts and internal scripts lies in where they are located: external scripts are usually, at least when the learners are not familiar with a certain learning situation, absent in the learners’ cognitive systems, instead. External scripts come from external sources. The earlier “at least when the learners are not familiar with a certain learning situation” is there for a reason: it is possible that external scripts will be at least partly internalized and therefore, they become internal scripts and present inside of the learner’s cognitive system, and learners are able to follow the script even though it is not with them. (Carmien, Kollar, G. Fischer & F. Fischer, 2007) Scripts exist not only in the field of education, for example, social norms are also scripts. One of the widely cited example of internal script is “the restaurant script” (Kollar et al., 2006; Fischer, Kollar, Stegmann & Wecker, 2013): when coming to eat at a restaurant, people act in a similar procedural and manner. However, an internal script such as the restaurant script can be an external script to some people: for example little children who is learning social norms.

In my research settings, all of the participants have been studying and practicing collaborative learning as the routine of their degree program, so how collaborative learning works in general becomes part of their cognition. But the research was scripted, only loosely scripted to some extent, taking the background of participants into consideration. The script used in the research concerns more about task-specific instructions, for example activity, group size, timetable, etc..

**The risk of over-scripting.** Though scripts are expected to facilitate learning in general, they also come with risks and flaws. A poorly defined or unsuitable script may backfire, especially when we consider applying scripts to diverse learning situations and learners. One of the risks I am talking about here is over-scripting (Weinberger et al., 2009; Dillenbourg, 2002). If the script used is too detailed and intense, it may restrict the natural interactions and thinking of learners, thus hinders collaborative learning
instead of fostering it. Also in my research, considering the background knowledge of participants, bearing in mind that it is designed to be a learning situation that solves an open problem, and to avoid being over-scripting, we designed the script to be informative but not too detailed.

2.3 Failure in learning and Learning from failure

Failure in learning can be caused by misconceptions, misunderstandings, slips, errors (Vanlehn, 1988) and many other reasons. Interestingly, most of the time, students are not aware of the fact that they are making mistakes, nor do they understand why mistakes and failure happen. But when failure happens, many students usually have negative emotions, and they see failure as something that has already happened and they can do nothing about it, or they just let it go. For example, when I was doing the literature review, I interviewed my cousin, who was a teenager junior high school student, for her opinion on education and failure in learning:

Me: *Tell me about what you think of failure in learning, for example if you failed an exam.*

Cousin: *If I failed an exam, I would feel guilty and sad.*

Me: *Why?*

Cousin: *I feel guilty because my failure would affect my parents and teachers, they will be upset and disappointed. But I also feel sad, it’s like a “slap in my face”, I feel sad to be so stupid to make mistakes and I also feel shameful.*

Me: *And then? Would you do anything about it?*

Cousin: *No, that’s everything. It already happened.*

Her answer was within my imagination and expectation: poor performance can pressure learners and cause negative emotions and perhaps undermine their motivation. I believe she is not the only one who think and behave this way.
Rather than a suggestion and proposal, learning from failure, especially in educational contexts, is a very important skill, which should be called for all people including students to acquire. Quality education has more than academic knowledge to offer, rather, it can help build other aspects that make us better human beings, such as values, views, thinking patterns and social skills, though those skills can be taught and learned in other contexts also.

One of the very basic hypothesis on learning from failure is that we acquire negative knowledge from failures, namely, instead of learning about what to do, we learn about what is wrong, what to avoid and what not to do. (Gartmeier et al., 2008) Learning from failure parallels with 21st Century Skills, which may be defined diversely by various bodies, but in general it refers to a complex body of various frameworks of skills and abilities required especially by the 21st century, in which the way of life, work, teaching and learning, social interactions and exposure to information are greatly influenced and changed by the very sophisticated and ever-developing communication and information technologies, compared with last century (Dede, 2010).

It does not necessarily mean that 21st Century Skills are only needed in the 21st Century but not in 20th century or 22nd century, it is named so just to emphasis the changes brought by the new era requires especially those abilities and skills. Even though there are many minor and major frameworks of 21st Century Skills, which are similar in general, emphasis on different details, they are complementary to each other and to simplify, Binkley et al. (2012) concluded a framework of 21st Century Skills which contains ten skills under four categories:

**Ways of Thinking**

1. Creativity and innovation

2. Critical thinking, problem solving, decision making

3. Learning to learn, Meta-cognition

**Ways of Working**
4. Communication

5. Collaboration (teamwork)

**Tools for Working**

6. Information literacy

7. ICT literacy

**Living in the World**

8. Citizenship – local and global

9. Life and career

10. Personal and social responsibility – including cultural awareness and competence

(Binkley et al., 2012, pp 18-19)

Though not included in the above list, seeing chance in failures and learn from failure falls into the umbrella 21st Century Skills. It is a skill that requires a mixed framework of abilities such as meta-cognition, creativity and innovation, decision making and problem solving skills. Also, it is very precious that this framework sees 21st Century skills applies not only in learning at school but also in career lives and living in the world, which supports the belief that the abilities to make the full advantages of failure benefits human not only in our school years, but also long-term personal and social life. In later sections, various literature contributed trying to look into, describe and explain how exactly people learn from failure.

2.3.1 Impasse Driven Learning

The term and theories of impasse driven learning, which was introduced by Brown and Vanlehn (1980) and Vanlehn (1988) is quite self-explanatory: it refers to a learning process which is driven by impasses. The literature is not new, actually is around 30 years old, yet it provides us with a very
constructive viewpoint and vision on how obstacles in learning such as impasses and mistakes can facilitate learning, also, even around 30 years has passed since the publication of the work, it is not out-of-date; instead, the theory of impasse driven learning explores the possibilities and mechanisms of learning from failures.

When students experience failure in learning, they either are aware of them during or after their working on the tasks: when they are trying to work on a task, they may run into “weird” situations, in which they sense that they are obviously running into a dead-end direction and that what is supposed to work, turned out a failure; or they seemed to work all fine but after their work are reviewed and marked, they are surprised to be informed that they failed in some tasks. These kind of “weird situations” learners run into, are like the situation described by the term impasse, which I will further introduce and discuss below in this section.

Many students experienced “dead-end” situations in their learning and problem-solving, when they realize that the ways of solution supposed or expected to work does not lead to the right answer or somehow goes to the wrong direction, leading them to a failure in their problem-solving or exercise practice. Vanlehn (1988) concluded from previous studies and also observation that impasse can happen in two different contexts depending on whether help from either the teacher, books, parents or any other sources are available when the impasse occurs. One typical situation where external instruction and help are not available is when students are taking exams. In this type of learning situation, students have no other choices but to “repair” what they already have done.

Impasse driven learning concerns about another type of learning situation: when external help is available. Then the students would extract from the help they receive a series of actions, which can be seen as a sub-procedure compared to the original hindered problem-solving procedure. As a result, the original problem-solving process halted by the impasse will be activated again by inserting the sub-procedure, which will lead the student to overcome the impasse and complete the learning process. The
The learning situation explained here is what we call impasse driven learning (Vanlehn, 1988). Even though long sentences with complex structure and clauses are used to explain, the term impasse driven learning still remains to be quite general and vague, waiting for more detailed to be added. In the following section the mechanism of impasse-driven learning will be further explored.

**Bugs, slips and systematic errors.** The impasses students experience when learning came with a large body of diverse reasons, for example carelessness, misunderstanding, misconceptions, mental block and so on, which can be concluded to be slips and systematic errors. To further understand how impasses happen, we need to distinguish slips and systematic errors. Systematic errors stem from consistent application of a faulty method, algorithm or rule. Slips, for example 5+8=12, refer to careless errors (Vanlehn, 1988). Both systematic errors and slips can be called errors, as slips are unsystematic careless errors. An error can be called systematic when there lies a procedure beneath his or her errors, if there is not a procedure behind, the error can be seen as unsystematic (Brown & Vanlehn, 1980). Among systematic errors and slips, only the former term can be further analyzed and used when studying the related theories and hypothesis, because the mechanisms of slips, which are unsystematic errors, and systematic errors are different. It is usually the case that even if students are following the right procedure and rules, errors and impasse occur. If we assume that students make no slips at all, then the rest of the obstacles can be called “bugs”, which also refers to the disturbance of the right procedure and rules. A systematic error can be represented by one or more than one bugs (Vanlehn, 1988).

**Stable, unstable bugs and bug migration.** It is quite interesting to stress that fortunately, bugs in human learning and cognition are not always stable, which means that bugs have a dynamic “life cycle”, they appear, disappear, evolve, or simply be replaced by other bugs (Brown & VanLehn, 1980). Though the mechanism of bugs is unclear and related studies lies across multiple disciplines such as educational psychology and cognitive psychology. We can still at least have a basic knowledge of the fact that bugs can be stable, and unstable. And according to Brown & Vanlehn (1980) and Vanlehn (1988), when a bug is replaced by a new one, it is called bug migration. To further explain, sometimes we can observe that
some students even tried, cannot change some of the bugs they run into, as if those bugs exist for a long period of time, and that they are part of the procedure of solving a problem encoded by the student during the learning process. Those types of bugs are so called stable bugs, as they seem to exist a relative long time. As for other bugs that only exist for a short while and then get developed, learned, or replaced or migrated by other bugs, they are unstable bugs (Vanlehn, 1988).

The Patch Hypothesis and the Repair Theory. Thanks to the knowledge that bugs are not stable, we can assume that human have the ability over control of bugs and thus avoid or eliminate systematic errors and mistakes in learning. In the first part of the Impasse Driven Learning section, Vanlehn (1988) gave us the definition of Impasse Driven Learning, which indicate that when learning is improved by impasses, students somehow can learn from the impasses and then find solutions, which enable them to work out with the right procedure and thus solve the problem successfully. But that is just a simplified explanation of Impasse Driven Learning. In the article, Vanlehn (1988) mentioned the patch hypothesis and the repair theory as a further illustration.

The ability to identify and learn from failure, impasses and mistakes is usually taken for granted that all students are born with the required skills. But it is not that simple and easy. When a student is able to learn from an impasse, we assume the student can recognize the impasse, which was experienced before. But only recognizing the impasse is not enough, the student must have a right solution to deal with the impasse. So here we can see an impasse-solution pair. These pairs are called “patches” (Brown & Vanlehn, 1980). Patches are not only pairs, but also can be interpreted as condition-action rules (Vanlehn, 1988). However this hypothesis explains how students learn from impasses to some extent, it looks somehow not precise. Because from the perspective of this hypothesis, students’ knowledge consists of patches and of course right core procedures, which are also condition-action rules, which brings a question, is there any differences between the condition-action rules of core procedures which was learned by students correctly originally and those generated from impasses and patches? I found another issue with the patch hypothesis: even though it offers us a possible explanation, the explanation of how students
find the patches is missing: it seems to me that according to this hypothesis, students experience an
impasse previously, then the next time they not only recognize the impasse but somehow magically
managed to find a solution to it. And that is it so that to learn from a certain impasse a student has to
experience the same impasse at least two times and that the two impasses have to be exactly the same or is
it so that impasses can be interpreted by students and thus extracted into abstract rules and procedure
instead of raw, intact impasses? Also, it seems to me that patches can be seen as problem-solution rules
while I believe to a certain problem, there can be more than one solutions. The hypothesis fails to stress
critical thinking on the “only one” right solution and the creativity and motivation to try different
solutions to a problem.

The mechanism may differ from individual learner to learner in reality, and the answers and
explanations could be found in other related literature and other resources, but I assume the purpose of
learning is not merely memorizing and storage of existing knowledge and facts, but also the ability to
extract the essence of knowledge and acquire rules so that students have the ability to innovatively use
what they have at disposal to solve various problems and after all, realize and develop their expertise,
though growing to be an expert in a certain field or discipline asks for time and different levels of
education.

Back to exploring how students learn from impasses, Brown and Vanlehn in their earlier work
back in 1980 introduced the Repair Theory (RT1), which was then extended and referred to as Repair
Theory 2 (RT2) by Vanlehn in 1988. In repair theory, the key is to repair impasses students run into when
solving problems in learning situations (Brown & Vanlehn, 1980).

The repair theory works similar with the way in patch hypothesis, the difference is that the patch
hypothesis focuses more on the result that the student finally manage to find pairs of “patches”, namely
solutions to solve certain types of impasses, while the repair theory tries to describe the process of trying
various ways and methods to find solutions. When running into an impasse, learners would try to solve
the problem themselves, in a meta-level local problem solving procedure (Vanlehn, 1988). In a local problem solving case, there is an initial state, a desired final state, and state-change operators (Vanlehn, 1988, Newell & Simon, 1972). Again, here the term state-change operator was borrowed from computer programming, mathematics and science, in which an operator appears to refer to a certain function, which has different meanings depending on the context. We can comprehend that state-change operators here refers to functions that change states. According to Vanlehn (1988), in a local problem solving case, the state-change operators do not change the state of the problem, instead, they change the interpreter which is executing the problem-solving procedure (Vanlehn, 1988). So when students got stuck by an impasse in learning and are trying to fix the situation, the initial state is the fact of being trapped by the impasse, the desired final state is getting rid of the impasse and the problem gets solved properly.

Repairs are the sequences of meta-level operators that succeed in getting students out of the impasse (Vanlehn, 1988). As mentioned before, during repairing, students are trying various methods to solve the impasse in a meta-level problem-solving procedure, so that repairing does not always lead to the right solution. Because during repair, students aim to solve the problem somehow, no matter the solution is proper and can be practiced repeatedly in similar impasses. There is also chance that repairing generates new bugs, or in some other cases, the initial bugs are replaced by other bugs, which is the so-called bug migration (Vanlehn, 1988).

According to RT1, it appears to me that the only action coping with impasses is to repair. From the lenses of RT1, imagine a typical learning situation in which RT1 is brought into practice. The key words of this situation might be, an individual learner, some impasses and meta-level problem-solving. Despite them, another hidden factor is that external help from any resources are not available, not allowed or not wanted by the learner. These settings parallel with a very common situation that all learners experience once a few time in their school years: during exams. But in real life, sitting exams is only one of the activities in school education. More often, during learning activities, external help, guidance or instructions can be found from various sources: textbooks, peers, teachers, and parents, reference books
and so on. Obviously, RT1 is not mature enough to explain a bigger picture. So Vanlehn then developed RT1 in 1988, thus comes RT2, which further complete the theory of impasse driven learning: we are back to the beginning of this section, the definition of impasse driven learning. The figure below may help us to have a better understanding of the different procedures of learning in RT1 and RT2:

![Diagram comparing Repair Theory 1 and Repair Theory 2](image)

*Figure 2. Comparing Repair Theory 1 and Repair Theory 2.*

Figure 2 is a simplified visualization of repair theory, RT1 and RT2. As RT2 is an update based on RT1, it covered the situation which has been explained by RT1.

There are theories of a large variety trying to explain learning from failure, among them impasse driven learning and the introduction of patches and repairs allows us to have an inner and closer look at the mechanism of failure-driven learning and learning from failure. However, there are more possibilities and explanations of how people learn from failures of both themselves and other people, suggested in the works of other researchers, for example Kapur (2008) Kapur & Bielaczyc (2012) Kapur & Rummel (2012), and Kapur (2014)’s studies on Productive Failure and Bandura (1971), Kim & Miner (2007), and Kapur (2014)’s studies of learning from vicarious failure.
2.3.2 Productive failure

Sometimes it is possible that failure in performance actually hides or leads into successful learning, and reversely, sometimes beneath outstanding performance lies poorer learning. Though it seems that both of the two types of cases sounds extreme and random, Kapur and other researchers (Kapur, 2008; Kapur & Bielaczyc, 2012; Kapur & Rummel, 2012; Kapur, 2014) introduced us researches of productive failure (PF): students struggle in defining and analyzing when solving complex problems under ill-structured and delayed instructions and may eventually fail in the task actually stand out, in case of learning, from students who succeeded in solving well-designed problems under well-structured direct instructions (Kapur, 2008). However the failure was designed on purpose by the researchers: Kapur and Bielaczyc (2012) state that their team’s work “is grounded in the belief that engaging novices to try, and even fail, at tasks are beyond their skills and abilities can, under certain conditions, be productive for developing deeper understandings” (pp. 46).

The design features of PF has taken some practical questions into consideration. There are students who just solve the exercise problem smoothly by strictly following the DI, but there are also some other students to whom the ready-made well-structured DI are too dry to follow: without understanding the abstract principles, rules, methods and skills given in the instruction, these students find it hard to progress further. This experience and feeling can find explanation from literature. For example, Kapur and Bielaczyc (2012) concluded that direct instruction (DI) can be problematic. Firstly, students receiving DI often are restrained by their prior knowledge and that they may not fully understand the domain-specific methods given in DI. Secondly, given DI alone, it can be hard for the students to understand why the DI has to be the way it is given. (Kapur and Bielaczyc, 2012)

As suggested in earlier paragraphs, productive failure is more “artificial” and “designed” than natural random learning situations. However, this theory does opens a window for us to have a better insight of the positive facade of the role of failure in learning. Also you can read from my research, which
can be found in later part of this paper that what I observed in my data looks much alike with Kapur’s PF cases: students are assigned to work in groups and to work on an open and complex problem with loose and open instructions, one of the groups spend long time struggling defining the problem and finally seems to fail in the task, but if you look deeper, students in that group actually came up with many interesting ideas with deep thinking. But the difference between my researches is that I and other researchers did not design the situation to be a PF case, instead, it naturally happened and was observed by me and other researchers.

2.3.3 Vicarious failure

Exploring failure in learning and learning from failure, we do not only learn from failures we produced by ourselves, sometimes, even when we are not so aware, we also learn from other people's failure, which can be called vicarious failure (VF), which concerns vicarious reinforcement, and vicarious learning from failures and near failures of others (Bandura, 1971; Kim & Miner, 2007; Kapur, 2014).

Bandura (1971) voices that self and vicarious reinforcement is based on a social context, in which people are constantly observing other people’s behavior and if they are punished, ignored or rewarded if they do something under some circumstances. Then the observer received some changes in their own behavior based on their observation and witness of the performance and consequences of other people. This is called vicarious reinforcement. Similar with the vicarious learning of individuals, Kim and Miner (2007) also support that learning from other organization’s experiences is an important way of organizations to gain knowledge.

Kapur (2014) in one of his researches compared vicarious failure (VF) with productive failure (PF). On one hand, there are a few reasons to support the belief of PF over VF: compared with students observing other’s failures, students experiencing PF are more engaged in the learning process and are better at understanding the differences between the target knowledge and their prior knowledge and false understandings because they are the ones who generate the ideas and thinking and experience in the
learning process. However, we can also find reasons to believe that VF is better than PF: VF is less cognitively consuming, in other words, the cognitive load of learning from PF is greater than that of PF; and students with relatively lower ability and knowledge can benefit more from VF than PF (Kapur, 2014).

Though the above mentioned comparison of PF and VF seems to make little sense because it suggests that PF and VF can beat each other in case of efficacy. However, it makes great sense because it revealed the important features, strength and weakness of both PF and VF, which gives a good unbiased review of the two techniques of learning from failures and errors. And it is worth mentioning that in real life, people experience both PF and VF, though probably not in research settings and not exactly following the theoretic framework of them, at least we both learn knowledge from our own thinking and experience as well as from experience especially failure of others; both ways are effective and means a lot to our knowledge building in both formal and informal learning contexts, both in short term and long term.
3 METHODOLOGY

3.1 Aim and research questions

The research focuses on failures in a group based on an open problem solving case. I have been constructing my thesis based on an interesting issue I noticed in the preparing stage: when I was an observer in my research, I thought that the group I was observing failed in both collaboration and the task, but when I looked back while transcribing the data, I realized my judgment at first was wrong: the group though experienced challenges, actually did a good job. This contrast in my thinking could stem from issues with evaluation and assessment of learning, but failure was the main issue that grasped my eyes and mind.

To be more specific, the key word is failure, however what I intend to test and examine is beyond failure. I base my hypothesis on the following viewpoints: firstly, performance does not necessarily indicate the quality of learning; secondly, under certain conditions, failure plays constructive role in learning. To further explain, my hypothesis are: firstly, poor or good performance does not indicate the failure or success in learning; secondly, students can learn from failures. To help me discover what I intended to see, I listed the research questions:

1. How did each group worked? How was the collaboration? Especially were there challenges or failures? How did each group deal with the challenges they faced?
2. How did each group reflect about their collaboration? Were they able to define the challenges, failures and strategies?
3. What did each group reflected about their learning from the session?

3.2 Research design and participants

The data of my study is based on the video records of a research project which was designed and carried out by a university research unit on February 11th, 2014 in a well-equipped learning and research
facility. I acted as an observer, together with five other observers and researchers. This project was designed originally to study:

*How can teachers or teacher students be supported for effective 21st century learning and interaction skills with use of collaborative ICT tools?*

*How can teachers or teacher students take advantage of the current introduction of mobile devices and social media into teaching and learning practices?*

*How to advance research methods for exploring learning and interaction in the context of teacher education?* (Online blogpost, Hyvönen, 2015)

Different from the original research intentions, I used the data collected in form of video recordings and written observation reports from this project to serve my own research purposes. Although I was not among the designers of this research, it is possible to carry out good research based on repurposed video collected with research questions different than the desired ones, with how the selection in previous phases affects the current research taken into consideration (Derry et al., 2010). Though aimed differently, I and other researchers in this project are telling different stories with the same data in our own researches, and should you be interested in reading all of our articles, a bigger picture will unfold itself with different viewpoints on the learning case we used as our data.

Before my explanation of the whole research design in greater detail, Table 1 explains the whole research process consisting three major stages of my studies concerning this thesis, each contains smaller phases:
Table 1 *A brief description of the whole research design and article writing process*

<table>
<thead>
<tr>
<th>1. Pre-research testing</th>
<th>2. Data collection (the whole process was video-recorded)</th>
<th>3. Data interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a. a trial procedure done by a group of researchers</td>
<td>2a. small group-based problem solving phase</td>
<td>3a. transcribing video recordings</td>
</tr>
<tr>
<td>1b. research interests and research questions drafted</td>
<td>2b. reflection phase all participants and researchers attended</td>
<td>3b. research interests and research questions decided</td>
</tr>
<tr>
<td></td>
<td>2c. observation reports from researchers and observers drafted</td>
<td>3c. literature review</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3d. final research directions and data analysis methods settled</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3e. coding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3d. analyze</td>
</tr>
</tbody>
</table>

A group of researchers participated in the pre-research trial session, which tested the practicality of the research design and provided a general expectation of the actual research sessions. The pre-research trial was not recorded and was not used as data in my research. Then the data was mostly acquired from the actual research sessions, which is divided into two parts: group problem-solving phase and reflection phase, both of which are video and audio recorded. Observation reports are also sources of my data. The observation reports are produced by researchers based on their observation during the whole research sessions. It needs to be stressed that the final reflection phase was the first time when participants, researchers and observers from other rooms could get to know about a group’s work and products.

In this research, participants were twelve first year and second year international Master’s degree students (seven female, five male) in the field of education. Not all of them had teaching experiences.
They had diverse educational backgrounds, and had their previous university degrees in the field of, for example, education, information technology, language and literature, psychology, finance and human resource. One thing in common was that all of the participants had good understanding, theoretic knowledge, and experience of collaborative learning. This was also a multi-cultural group of participants, with their countries of origin scattered all over the world: Brazil, Bulgaria, Romania, Canada, Portugal, China, Finland, Italy, Russia, Turkey and Uganda. Despite their diverse educational and cultural backgrounds, all of the participants spoke fluent English. The language of instruction of the Master’s degree program is English, and also the language used in all communications and printed materials in this research was English. All of the participants knew each other, although some of them were more familiar with each other than with others. Please refer to Table 2 for the groupings of the groups.

Table 2 Participants in each group

<table>
<thead>
<tr>
<th>Group Apple</th>
<th>Group Grape</th>
<th>Group Banana</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lynn</td>
<td>Dany</td>
<td>Floyd</td>
</tr>
<tr>
<td>Zoe</td>
<td>Penny</td>
<td>Tom</td>
</tr>
<tr>
<td>Marsha</td>
<td>Sarah</td>
<td>Sam</td>
</tr>
<tr>
<td>Peter</td>
<td>Amber</td>
<td>Dianna</td>
</tr>
</tbody>
</table>

The whole problem-solving process and the reflection part were observed and filmed for data collection and further analysis. The twelve participants spontaneously formed three groups of four, all groups then were assigned the same open-ended problem-solving task, which required each group to work on a three-hour-long epistemic game in three separate rooms. In each of these three rooms, there were
four participants, one student observer and one researcher. Although it seems that we could observe a bigger group of twelve participants together, small groups, however, is an important contribution to effective collaborative learning, because ideally, a successful collaborative group contains four to five members (O’Donnell & Hmelo-Silver, 2013; Vuopala, 2013). If there are eight or more than eight members in a group, students will automatically split into smaller groups (Vuopala, 2013). Based on this belief, we arranged three rooms, each contains four participants as a group. Also, the environment in which the research was carried out together with small group size created a safe and secure atmosphere to participants, which is also believed to facilitate collaborative learning (O’Donnell & Hmelo-Silver, 2013).

Observers and researchers were assigned to be in the rooms together with the groups, however, they were not supposed to interfere too much during the research process. The observers and researchers were supposed to be in the room to have closer observation of the problem solving process and produce observation notes. Participants took part in a three-hour long epistemic game, in which they were required to solve an open problem with different tools at their disposal (candies, scientific articles on relevant topics, pens and paper, iPads, wireless internet connection, walls with writable surface, and Lego blocks), groups could negotiate, discuss and decide what is the core problem, what tools to be used and also they could design their own problem-solving strategies at their will. There were no limitations to means of communication either, but thinking aloud was encouraged. The open problem in this epistemic game was “How does teachers’/ educators’ role will change over the next 20 years?” Being an open problem-solving case, this research has no standard problem-defining or standard answers, as long as groups work collaboratively and effectively, and finally produce results which are reasonable, logical and make good sense. The whole problem-solving project was intentionally designed to be open and loosely scripted, which gives sufficient freedom to the participants to explore and work together. In the research settings, all of the participants have been studying and practicing collaborative learning as the routine of their degree program, so how collaborative learning works in general becomes part of their cognition. So the script used in the research concerns more about task-specific instructions, for example activity, group size,
timetable, etc., but less about what is collaborative learning and how should participants do to work collaboratively. Considering that the research is designed to be a learning situation in which learners work in groups to solve an open problem, and to avoid being over-scripting, we designed the script to be informative enough but not too detailed.

3.3 Analysis

The very first phase of data analysis started right at the beginning of the research session. Observation notes and reports were produced by researchers and observers. Then the video data, transcripts and observation reports together make the whole data used in my research. Eventually the research topic and research questions were settled after months of video watching, transcribing, and literature searching. Then comes the literature research phase, in which the relative articles provided me with theoretical support and enrichment to my hypothesis from existing researches done by other researchers. Meanwhile, I looked back to my data from time to time, and tried to combine theories with my data.

Afterwards I focused on my data again, and started the coding and analysis phase. I decided to use a qualitative research methods to code and analyze my data. According to Brink (1993),

The term qualitative research is really an umbrella term representing a variety of research approaches which share certain common elements. Qualitative researchers are not interested in causal laws but in people’s belief, experience and meaning systems from the perspective of the people. Methods used are more subjective than in quantitative research and do not include statistical analysis and empirical calculation (Brink, 1993, pp. 35).

At this stage, selection research is crucial, because a researcher need to decide which elements of a complex environment during the research should be sampled for further analysis (Derry, Pea, Barron, Engle, Erickson, Goldman & Sherin, 2010). In the data coding phase, I borrowed the Functional Category System (FCS) (Poole & Holmes, 1995), which was originally designed to study the decision development
in computer-assisted group decision making, but it offered more possibility to have more insight to the data and I found it helpful in my research categorizing the interaction among participants in different phases and development stages of their group-based problem-solving process in the following manner, see Table 3:

Table 3 Decision Function Coding System Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Problem definition</strong></td>
<td></td>
</tr>
<tr>
<td>1a. Problem analysis</td>
<td>Statements that define or state the causes behind a problem</td>
</tr>
<tr>
<td>1b. Problem critique</td>
<td>Statements that evaluate problem analysis statements (may be assigned positive [+] or negative [-] valence)</td>
</tr>
<tr>
<td><strong>2. Orientation</strong></td>
<td></td>
</tr>
<tr>
<td>2a. Orientation</td>
<td>Statements that attempt to orient or guide the group's process. These also include simple repetitions of others' statements or clarifications</td>
</tr>
<tr>
<td>2b. Process reflection</td>
<td>Statements that reflect on or evaluate the group's process or progress</td>
</tr>
<tr>
<td><strong>3. Solution development</strong></td>
<td></td>
</tr>
<tr>
<td>3a. Solution analysis</td>
<td>Statements that concern criteria for decision making or general</td>
</tr>
<tr>
<td>3b. Solution suggestion</td>
<td>Suggestions of alternatives</td>
</tr>
<tr>
<td>3c. Solution elaboration</td>
<td>Statements that provide detail or elaborate on a previously stated alternative. They are neutral in character and provide ideas or further information about alternatives</td>
</tr>
<tr>
<td>3d. Solution evaluation</td>
<td>Statements that evaluate alternatives and give reasons, explicit or implicit, for the evaluations. They may be assigned positive (+) or negative (-) valence. Statements that ask</td>
</tr>
</tbody>
</table>
for evaluations or are bivalent are coded as neutral (/)

3e. Solution confirmation: Statements that state the decision in its final form or ask for final group confirmation of the decision. They may be assigned positive (+) valence if they argue for confirmation, or a neutral (/) valence if they merely ask for confirmation. Negative responses to 3e statements are coded 3d-parameters for solutions

4. Nontask: Statements that do not have anything to do with the decision task. They include off-topic jokes and tangents

5. Simple agreement

6. Simple disagreement

Note. Retrieved from Poole & Holmes’ article Decision Development in Computer-assisted Group Decision Making published in 1995, in Human Communication Research, on pp. 104. However this coding method is not 100% suitable for my research, yet still, this method is very helpful for me to chunk the whole conversation into smaller pieces based on their functions, and thus the selection of materials is facilitated.

Then after the coding phase, the analysis and results are presented in later sections in the following logic. I used the following materials I collected from the research to fulfill my research purposes, see Table 4:
Table 4 *Materials used and purposes they served*

<table>
<thead>
<tr>
<th>Material</th>
<th>1. Video recordings and transcripts of the problem-solving phase</th>
<th>2. Observation reports produced by researchers and observers in each room</th>
<th>3. Video recordings and transcripts of the reflection phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>visualize the general timelines and working sequences of each group</td>
<td>complete the explanation of the timelines and working sequences of each group</td>
<td>present the reflection of each group, especially the awareness of challenges and failures and the application of strategies</td>
</tr>
</tbody>
</table>

To further explain, as it is suggested by the theoretical framework and research questions, the key words this research is focusing upon are performance, learning, and learning from failure. First of all, based on the video data and transcript of the videos of the problem-solving sessions, general pictures of the working sequences, timelines and products of all the three groups of participants will be presented. The general pictures of the working sequences and timelines can help to visualize the differences of all the three groups in their work during the whole process. Also, the timelines will indicate how and what did the groups learned and produced during the problem-solving process. Then with the observation reports and feedback produced by observers and researchers, a supplement to the timelines can be seen. After those two parts of analysis, an insight of the differences between the learning and performance in each group can be found out. Also, challenges or failures of each group will be collected and analyzed with
participants’ reactions to the obstacles taken into consideration. Eventually, the research questions could be answered and the hypothesis can be tested.
4 RESULTS

4.1 Timelines and working manners

In this section important stages of collaboration and events during the process will be marked, to produce a brief look of how the different groups worked. However, timelines only are able to cover a small part of the stories. The observation reports produced by researchers and observers in each room act as reasonable supplement to the timelines, presenting a more detailed and specific description of how each groups of participants worked. All observers and researchers were following a template of the observation reports, which guided the observers and researchers to pay attention to questions focusing on four aspects, see Table 5:

Table 5 Observation questions to researchers and observers

<table>
<thead>
<tr>
<th>Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>How active is the group?</td>
</tr>
<tr>
<td>Is participation equal by each group member?</td>
</tr>
<tr>
<td>Are all opinions and viewpoints accepted and discussed equally?</td>
</tr>
<tr>
<td>How would you describe power relations between group members?</td>
</tr>
<tr>
<td>Do participants have same or different styles of working?</td>
</tr>
<tr>
<td>Which roles (e.g. leader, free-rider) does the group members take and how the roles are taken (e.g. spontaneously)?</td>
</tr>
<tr>
<td>How critical are the discussions?</td>
</tr>
<tr>
<td>How does the group coordinate its’ activities (timetable, progression etc.)?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Atmosphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>How would you describe the group atmosphere (e.g. relaxed, safe, trustful, humorous, tense, playful, and creative)?</td>
</tr>
<tr>
<td>Is anyone showing extreme positive/ negative emotions?</td>
</tr>
<tr>
<td>Are there any conflicts occurring?</td>
</tr>
<tr>
<td>Are all group members motivated toward the task?</td>
</tr>
</tbody>
</table>
Note. The observation questions were designed by Vuopala, E., Hyvönen, P., & Kaisto, J., in 2014, retrieved from the printed materials used in the PROMO project, 2014.

Material used in this section were video recordings, transcripts and the observation reports produced by the researchers and observers along with the groups’ working sessions.

4.1.1 Working process of Group Apple

Table 6 is the timeline of Group Apple during the problem-solving process. Based on my coding models mentioned in the previous section, the whole process was divided into small chunks, each contains smaller events, which were marked with the time of their starting points. The video recordings used at this phase covered the problem-solving process of all the three groups, which naturally contains two parts, before the lunch break and after the lunch break, see Table 6:

Table 6 Timeline of Group Apple during the problem-solving sessions

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Signs of events (fragments of conversation, for example) or notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:00:38</td>
<td>researcher announced the start</td>
<td>R: <em>Okay, so you can start.</em></td>
</tr>
</tbody>
</table>
| 00:00:42   | group formation started, candy helped group forming                    | L: *So the group formation?*  
M: *So...we need to find our social cognitive and emotional common ground...*  
Z: *Hmm...* |
<table>
<thead>
<tr>
<th>Time</th>
<th>Task Phase</th>
<th>Dialogue</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:01:48</td>
<td>group formation</td>
<td>P: I don’t know what we are supposed to do.</td>
</tr>
<tr>
<td></td>
<td>finished</td>
<td>Marsha: Well, I think, we are already arranged our materials and stuff.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L and P: Hmm...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M: and formed the group and we know each other.</td>
</tr>
<tr>
<td>00:02:10</td>
<td>norming started</td>
<td>L: And here we can use this page. There are some instruction.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M: Hum? No, that’s for the end.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L: Oh.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Z: @@@</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M: That’s for the aquarium part, at the very end.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L: Oh.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P: Are we writing the answer here? How we are answering this task?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L: On this page?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M: Do we need to write it here?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Z: We have to write the phases, how we doing...what we do...but the final...where is the final? Here! End result is here. So we have to...we can use a text, a figure or something</td>
</tr>
<tr>
<td>00:05:50</td>
<td>brainstorming started,</td>
<td>P: Hmm. Well the next thing is defining the...</td>
</tr>
<tr>
<td></td>
<td>defining the goal</td>
<td>L: The need</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M: The problem</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P: Need, problem, goal...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Z: What is the problem?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M: Ok let’s move on to that one...</td>
</tr>
<tr>
<td>Time</td>
<td>Event</td>
<td>Conversation</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>00:24:40</td>
<td>impasse detected, external help (articles) stepped in, reading started</td>
<td>M: <em>Should we look at this stuff? What this smart people say that will happen?</em></td>
</tr>
<tr>
<td>00:25:00</td>
<td>backed to discussion again, while reading at the same time</td>
<td>P: <em>Was that the context about how the world will change and then... how knowledge will change, how children have access to the context very easily and it’s more about how to filter that and their study skills. L and M: Yeah.</em></td>
</tr>
<tr>
<td>00:30:10</td>
<td>conversation stopped, reading started again</td>
<td></td>
</tr>
</tbody>
</table>
| 00:31:40 | backed to discussion, started with reviewing articles, trying to define the core problem | M: *This article is also talking that teacher’s role in an online community, should be considered, and online community doesn’t necessarily mean that it’s free of any control, that teachers should have some kind of moderator role there.*  
|        |                                                                     | -----                                                                                         |
|        |                                                                     | Z: *But, I mean, my question is do you think this could be the problem? How to prepare for these changes?*  
|        |                                                                     | L: Yeah.                                                                                      |
|        |                                                                     | M: Yeah. But...                                                                               |
|        |                                                                     | M: *Or, is what the problem that how to provide... the kind of... the support for children to be able to integrate in the society. That will help them accomplish those...acquire those skills that they will need to be able to be lifelong learners and things like that.* |
| 00:38:40 | started using mind-maps to collect and organize ideas                | M: *Should we make just a quick mind map with everything we discuss? Then we will have the lunch break.*  
<p>|        |                                                                     | P: <em>I...</em>(doodling on a paper)                                                                |
|        |                                                                     | All: @@@                                                                                     |
|        |                                                                     | M: <em>Because we will go for lunch in ten minutes and...</em>                                        |
|        |                                                                     | P: <em>I...I don’t know which we could put in the center.</em>                                       |
|        |                                                                     | M: <em>We can leave the center and we can have teachers.</em>                                      |
|        |                                                                     | L: Umm.                                                                                       |
|        |                                                                     | P: Yeah, one word at a time.                                                                 |</p>
<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Conversation</th>
</tr>
</thead>
</table>
| 00:50:11 | lunch time started                 | P: *Lunch?*
M: *Yeah.*
P: *Good.*
L: *So we will discuss later.*
P: *Yup.*
M: *Ok.* |

After lunch break

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Conversation</th>
</tr>
</thead>
</table>
| 00:00:50 | prepared                           | L: *So we are in the 5: Possible Solutions.*
M: *No. We are done.*
L: *Ok.*
M: *Four I think. Core of the problem.* |
| 00:03:50 | core problem defined              | L: *Yeah. The core of the problem.*
M: *OK so we have that.* |
| 00:07:05 | direction of solution found        | M: *Do you think we go one by one the roles that we mentioned and try to see what kind of skills that they need to do those things?* |
| 00:37:46 | started preparing presentation     |                                                                             |
| 01:32:40 | started presenting to the camera   |                                                                             |
| 01:39:17 | finished presentation              |                                                                             |

Note. R=researcher, M=Marsha, L=Lynn, P=Peter, Z=Zoe, @@=laughter, clipped fragments are divided by -----.

As we can see from Table 6 that Group Apple’ working procedure was very fluent, starting with forming a group, then gradually decided how to collaborate, defined the task, core problems and solutions through good collaboration with the help of good collaboration skills. In general the group was very active in collaboration as a group during the whole problem-solving process.
What can also be observed, but not visible from the above timetable is that all of them had equal contribution in the whole process, they discussed actively and had on-task thinking quite equally; even though different working styles, personalities and role-takings can be observed, they managed to negotiate and find a way which allows smooth collaboration and a positive way of thinking can be detected throughout the whole process even though at the beginning they had difficulty relaxing and motivating themselves. They managed to motivate each other and kept their working on the right track. The group followed the instruction given to them, and because of good knowledge and experience of collaborative working, they seemed to know what to expect and what they were supposed to do during the whole process; for example, they knew that they needed to actively participate and make equal contribution, and they had the ability to select and evaluate the tools provided to better serve their needs, but in a more traditional way.

In the group processing aspect, we can see that also this group’s working procedure partly follows the “Forming, Norming, Storming, and Performing” model (Tuckman, 1965). However, as the model concerns more about the development phases of strangers, and that Group Apple mentioned that they knew each other and some of them had collaborated before, the group reached the performing stage quite fast. Based on my observation, the group’s practice was with less conflicts, or the conflicts were so subtle and mild that it was hard to recognize. This may indicate that the group had very good collaboration and regulation skills.

Very soon after the researcher announced that they could start, all group members seemed to be ready in the working mode. Then they started working by forming the group. The group forming stage seemed to be very short. They skipped the stage to introduce themselves and to find common ground. They had the challenge to motivate themselves though. Interestingly, candies significantly helped soothing and relaxing the moods and Group Apple was more motivated for the task afterwards.
Then in the norming phase, they negotiated and decided how they work together and how they present the final product. They actively discussed and decided the related issues. After that, they spent most of their time brainstorming, in which they approached the problem, defined the core problem, discussed about possible solutions and finally decided the solutions to the core problem they have.

The introduction of reading articles after their primary discussions marked the performing phase into two smaller parts: they started with broad and less-organized ideas, but after reading the articles, they managed to narrow down their discussion and became more focused and determined. It is worth mentioning that though the group decided to read from the article, they managed to chunk the reading time with conversations developing their ideas and thoughts, thus they kept the interaction and conversation going fluently instead of long-time silent reading.

Also it was very obvious that they had a long enough period of time to conclude their thinking while preparing their final presentation. Then at the end, they presented their solution to the camera collaboratively, if one of them was talking, the rest are listening carefully and were able to fix any mistakes or missing points. We can see the selection of tools was rather traditional, but it served their purpose well. The tools they used included instructions sheets, candies, scientific articles, mind-maps, laptop, pen and pencils: candies helped forming the group, articles gave them more theory-based inspirations, pens, papers and mind-maps helped them organize their thinking, laptop was used to prepare the final presentation.

The group were following the instruction quite closely, I could see that they were filling in the chart what stage they just finished and they knew what they were supposed to do in the next step. They started using the mind-maps before lunch break because Marsha suggested that they may forget what they have already discussed would be forgotten because of the lunch break. They organized and kept record of their ideas, and the mind map helped them to collect their ideas and became one of the major support to their creating of the final presentation. In their final presentation they embedded in the PowerPoint
presentation tables, figures and texts. The final presentation was well-designed and follows a very logic order.

In the observation report, the two researchers observing Group Apple also voiced interesting opinions. Both of them agreed that in general all participants had equal contribution in the group, though at different stages some of them were talking more than the others and some of them took the role as a leader or coordinator, and sometimes there was no obvious role-taking, the group worked in a diplomatic manner under a safe, positive and relaxed atmosphere: no tension moments were observed, none of the members showed negative attitudes.

The observer noticed that the group had challenges other than the uncertainty of the task at the beginning: in the production phase, all members said they were not good at drawing. But Group Apple defeated the challenge: Peter started drawing though he said he was not good at it, then gradually everyone contributed in the drawing.

4.1.2 Working process of Group Grape

Similar techniques applied to Group Apple was used to analyze Group Grape’ working sequences. In the “Signs of events” column, both fragments of conversation and notes from researcher were used, because some of the beginning points of events could be seen in their verbal communications, some of them instead, could be observed in the video recording. Table 7 shows the timeline of Group Grape in the problem-solving sessions.

Table 7 Timeline of Group Grape during the problem-solving sessions

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Signs of events (fragments of conversation, for example) or notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:00:35</td>
<td>researcher announced the start, candy helped group forming</td>
<td>R: Okay, so you can start.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D: You know any good ones?</td>
</tr>
<tr>
<td>Time</td>
<td>Event Description</td>
<td>Dialogue</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| 00:01:50 | started handing out material and tools                                             | P: Hm?  
D: Which ones are good?  
S: Those.  
D: Okay, what’s inside? It’s cloud-berry?  
S, P: No.  
S: That’s something...  
P: But these are, awesome, like chocolate, chocolate, and chocolate. |
| 00:02:15 | group forming finished, started working by reading instructions                    | S: We can start.  
A: Yeah, I think we can start. |
| 00:02:27 | norming started                                                                   | S: First we should fill our space...erh...  
A: The paper?  
S: Yeah. |
| 00:05:35 | brainstorming on the task started                                                 | P: I’m thinking, I don’t see any problem in this question. I mean, it’s just a question. Like, how does teacher’s role changes over the next twenty years.  
S: I’m thinking that I agree. Is it a problem or is it just a normal situation, because everything changes, and, you just have to be prepared, to everything changing.  
A: Probably I think, that the main point would be, since we cannot predict exactly how the situation would be in 20 years, maybe we can, ah...The main point is education should become more agile, so maybe decision...What we should think of, more adaptable kind of education? |
| 00:06:40 | turned to articles, discussed about splitting the task, started reading            | D: Have you guys read the articles?  
All: No.  
A: They are here. Should...  
S: Should we have a look? |
<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Notes</th>
</tr>
</thead>
</table>
| 00:09:15 | backed to norming again                          | P: *Oh, for the articles, we have how many hours for that, for all the activity, like three or something four?*  
S: *No idea at all. There’s a break.*  
D: *Hope there’s a lunch break.*  
P: *Yeah.* |
| 00:11:25 | backed to reading; A,P,S was taking notes         | (quiet reading)                                                      |
| 00:48:40 | backed to brainstorming by summarizing articles    | D: *I, erh, this one was an introduction article, I think it...*(Only the beginning of his saying was shown here because it was a long talking.) |
| 00:50:53 | Lunch break                                      | R: *Lunch time.*                                                      |
|         |                                                   | **After lunch break**                                                 |
| 00:00:40 | researcher gave more instruction, participants asked questions | R: *So this session end at one o’clock. So you have nearly two Hours.*  
D: *Cool.*  
P: *What exactly should be done at one o’clock?*  
S: *Solution?*  
R: *Yes, solution. But now you have read all the articles, so I think you should just do the task. And try to be creative, not this common sense like, what is written on the articles, something else, use the space.* |
| 00:01:23 | brainstorming continued                          | D: *Let’s review again?*  
P: *Well yes.*  
D: *Do you guys remember what I said or you want me to repeat it?*  
P: *Well I guess I remember.* |
| 00:22:33 | reading started again                            |                                                                      |
| 00:22:50 | backed to brainstorming                           | P: *Core of the problem we defined or have we just...*  
D: *Humm, core of the problem is the question, the same as the* |
question, is this?
A: (cannot hear)
D: Yeah.
A: This, how does teacher’s role will change over the next 20 years?

<table>
<thead>
<tr>
<th>Time</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01:04:19</td>
<td>conversation stopped, silence for a while</td>
</tr>
<tr>
<td>01:05:10</td>
<td>continued discussion</td>
</tr>
<tr>
<td>01:13:47</td>
<td>end of discussion</td>
</tr>
<tr>
<td></td>
<td>(They left the final presentation to the next stage: reflection of each group with all the rest of participants and researchers)</td>
</tr>
</tbody>
</table>

**Note.** P=Penny, D=Dany, S=Sarah, A=Amber, R= researcher, words and sentences in “( )” are notes and explanations from researcher.

In general, we can see from Table 7 that Group Grape worked as a group quite actively and with equal contribution. However, Group Grape was not very motivated for a longer period of time and had shown much negative thinking. Looked close at more details, Group Grape had a lot of critical thinking, both on the task itself and also on the sub-topics in their discussion.

Candies also helped the group to relax and break the ice, which helps forming a group. The group started conversation by discussing and sharing the candies on the table. Group Grape skipped the step to introduce themselves and find common ground. After they read from the instructions that they were supposed to answer the question of “How does teachers’/ educators’ role will change over the next 20 years?” They started brainstorming immediately, criticizing how vague and poorly defined was the question they were about to find answer to. So later they decided to cooperate, each of them read one of the articles they were provided, and see if they can find more information or clues to the answers from the articles. After they have assigned the articles, they started reading quietly, some of them were making some notes during the reading. The group was finally back to conversations after quietly reading for
around half an hour. They restarted their conversation by reviewing and summarizing the articles they just read. However the conversation was halted by the lunch break.

Then after the lunch break, the session started with some instructions and tips from the researcher. Then one of the participants asked from the researcher what exactly they were supposed to produce. The researcher gave them some suggestions instead of straight forward answers. Then they immediately were back to brainstorming, continuing their review of articles, which was not finished before lunch. After that they became more focused in topics and produced very interesting and deep ideas afterwards. They spent some time reading after lunch also, but different with their reading before lunch, this time their reading only lasted few minutes, which was followed by conversation again. It is worth mentioning that Group Grape were having some short off-task talks which usually end up in laughter, which helped building trust and sense of belonging among group members. Group Grape did not have the phase to summarize the results of their discussions, instead, one of the participants volunteering took the role as a note-taker, who was making notes and keeping traces of what they had discussed.

Group Grape’ choice of tools were quite traditional. Candies, instructions sheets, articles, pens and papers were used. The group were considering using Lego blocks and PowerPoint for the final presentation but these options did not really worked. Candies helped breaking the ice, after which came the instruction sheets, then articles were used; during the reading and later discussion process, pen and papers played the role to make notes.

An issue which was quite obvious to see from the video recordings was that the group had difficulty making sense of the task and defining the problem. And they considered the original question “How does teachers’/ educators’ role will change over the next 20 years?” as the core problem they are solving instead of defining the problem in a more specific way. However, as it was expected to be a session in which participants work collaboratively to solve an open problem, it is the participants’ freedom to define the problem and find solutions, Group Grape’ defining of the problem was not a failure,
it was a matter of choice. On the bright side, another issue can be observed was that even though the 
group had difficulties making sense of their task, they were complaining, they were trying hard and 
paying effort and finally managed to kept collaboration and actually had produced very interesting and 
deep ideas.

At the beginning, some of them said they did not understand why they were there and what they 
were supposed to do. When trying to define the goal, complaints such as “it’s too vague”, “it’s too big, the 
task”, “it makes no sense to me” can be heard quite often, which indicate their negative emotions during 
the sessions. But put the complaints aside, Group Grape were good at critical thinking, and they actually 
managed to develop their discussion gradually, produced deep thinking and good final solutions. However, 
the group failed in defeating the feeling of uncertainty and unmotivated.

In the observation reports, the researcher and observer were quite critic about Group Grape’s 
work. Both of the reports mentioned that the group had a bored but “let’s do this” atmosphere. At the 
beginning, one of them started criticizing the task, saying it was too vague and it was impossible and it 
would make no sense to dork on the task. Later on the whole group got influenced and were quite critical 
and pessimistic. There was no obvious role-taking in the group, however, all participants had equal 
participation and contribution in the working process. Not all of their ideas and suggestions were heard or 
followed, but all of them could had their ideas voiced. For example, at some point, one of them suggested 
to use some tools, others seemed to either ignore or reject, either silently or by saying the tools were not 
suitable or helpful.

At this point, I would say the timetable suggests that Group Grape did a fairly good job, even 
though they were not very motivated and they were criticizing, they were able to keep collaboration 
carried out. However the observation reports focused more on the negative side of Group Grape.
4.1.3 Working process of Group Banana

Group Banana had quite a different timeline and working sequence than those of other two groups, thus my organizing of their timeline will be adjusted a little bit to better explain what happened with Group Banana. In order to present the situation when Group Banana sometimes were separated into subgroups and individuals, the “Event” boxes were divided into several smaller boxes, each tells sub-events done by different smaller groups or individuals; also, to better illustrate the features of the working sequences of the Group Banana, the “Fragments of conversations” column was replaced by a “Note” column.

Table 8 Timeline of Group Banana during the problem-solving sessions

<table>
<thead>
<tr>
<th>Time</th>
<th>Note</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:01:40</td>
<td>researcher announced the start</td>
<td></td>
</tr>
<tr>
<td>00:01:45</td>
<td>Floyd gave some introduction on his situation</td>
<td></td>
</tr>
<tr>
<td>00:02:15</td>
<td>started preparing for collaboration</td>
<td>started sharing printed materials, having conversations at the same time</td>
</tr>
<tr>
<td>00:02:42</td>
<td>participants started focusing on different things</td>
<td>Floyd suggested start working, then left his seat to the back of the room</td>
</tr>
<tr>
<td>00:02:49</td>
<td>Dianna left seat to find pens</td>
<td>Sam and Tom quietly reading the instructions</td>
</tr>
<tr>
<td>00:03:37</td>
<td>Dianna left room</td>
<td></td>
</tr>
<tr>
<td>00:03:42</td>
<td>started group forming</td>
<td>Floyd came back, trying to lead the group start working</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sam and Tom were ready to work</td>
</tr>
<tr>
<td>Time</td>
<td>Event</td>
<td>Notes</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------------------------</td>
<td>--------------------------------------------</td>
</tr>
<tr>
<td>00:04:15</td>
<td>discussion started</td>
<td>Floyd was quiet</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sam and Tom started their discussion,</td>
</tr>
<tr>
<td>00:05:55</td>
<td>Dianna came back</td>
<td></td>
</tr>
<tr>
<td>00:06:19</td>
<td>two sub-groups of two formed</td>
<td>Floyd started help Dianna understanding the instructions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sam and Tom continued their discussion</td>
</tr>
<tr>
<td>00:06:54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00:07:20</td>
<td></td>
<td>Floyd and Dianna started norming</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sam and Tom continued discussion</td>
</tr>
<tr>
<td>00:07:30</td>
<td></td>
<td>Floyd and Dianna halted conversation</td>
</tr>
<tr>
<td>00:08:08</td>
<td></td>
<td>Floyd and Dianna backed to norming</td>
</tr>
<tr>
<td>00:09:31</td>
<td>Floyd left Dianna to his own seat</td>
<td>Dianna started silently reading the instruction and playing with Lego</td>
</tr>
<tr>
<td>00:10:55</td>
<td>researcher stepped in</td>
<td>All participants stopped what they were doing and listened to the researcher</td>
</tr>
<tr>
<td>00:11:30</td>
<td>sub groups formed again</td>
<td>Floyd was quiet</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dianna looking at Sam and Tom</td>
</tr>
<tr>
<td>00:13:41</td>
<td>Dianna was invited to join in the existing group of two</td>
<td>Dianna started conversation with Sam and Tom, Tom briefed Dianna the situation</td>
</tr>
<tr>
<td>00:16:16</td>
<td>researcher stepped in</td>
<td>everybody stopped and listened to the researcher</td>
</tr>
<tr>
<td>00:17:30</td>
<td>reading started</td>
<td>Dianna started reading while using iPad, others reading</td>
</tr>
<tr>
<td>Time</td>
<td>Event</td>
<td>Notes</td>
</tr>
<tr>
<td>---------</td>
<td>--------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>00:23:00</td>
<td>discussion started again</td>
<td>Floyd voiced his idea, started discussion with Sam and Tom</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dianna seldom joined</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sam and Tom followed Floyd and started discussion</td>
</tr>
<tr>
<td>00:48:38</td>
<td>researcher stepped in</td>
<td>found out that the core problem was not defined yet and the solutions is waiting in the to-do list</td>
</tr>
<tr>
<td>00:49:30</td>
<td>left for lunch</td>
<td></td>
</tr>
<tr>
<td></td>
<td>After lunch break</td>
<td></td>
</tr>
<tr>
<td>00:01:17</td>
<td>individual presentations started</td>
<td>Floyd started presenting his ideas via drawing and writing on the board, others watching and listening to Floyd</td>
</tr>
<tr>
<td>00:11:52</td>
<td></td>
<td>Sam started drawing, writing and presenting his ideas, others watching him</td>
</tr>
<tr>
<td>00:12:47</td>
<td></td>
<td>Dianna started playing with Lego</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Floyd was resting at the back</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sam presenting his ideas while Tom discussing with Sam</td>
</tr>
<tr>
<td>00:22:45</td>
<td></td>
<td>Sam finished presentation, Floyd joined conversation with Sam</td>
</tr>
<tr>
<td>00:26:33</td>
<td></td>
<td>Floyd joined Dianna in Lego building</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sam and Tom continued talking</td>
</tr>
<tr>
<td>00:27:44</td>
<td></td>
<td>Floyd left Dianna to his own seat, silent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dianna continued with Lego</td>
</tr>
<tr>
<td>00:29:25</td>
<td>researcher stepped in</td>
<td>the group was reflecting what they did to the researcher</td>
</tr>
<tr>
<td>00:29:53</td>
<td>decided to summarize</td>
<td>Dianna suggested to sum up their thinking and try to reach agreement</td>
</tr>
<tr>
<td>00:30:30</td>
<td>researcher stepped in</td>
<td>Floyd and Dianna worked on Lego</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sam and Tom continued discussion</td>
</tr>
<tr>
<td>00:31:23</td>
<td>researcher stepped in</td>
<td>the group decided to explore and present solutions and started discussion</td>
</tr>
<tr>
<td>00:36:53</td>
<td>silence started</td>
<td>awkward silence</td>
</tr>
<tr>
<td>00:37:13</td>
<td>attempt to voice ideas</td>
<td>Floyd talked, received no response, silence continued</td>
</tr>
<tr>
<td>Time</td>
<td>Activity</td>
<td>Details</td>
</tr>
<tr>
<td>----------</td>
<td>-----------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>00:37:38</td>
<td>started discussions</td>
<td>Dianna voiced her ideas, started discussion as a group</td>
</tr>
<tr>
<td>00:46:57</td>
<td></td>
<td>Dianna started building Lego again</td>
</tr>
<tr>
<td>00:48:10</td>
<td>discussion continued</td>
<td>Dianna was building Lego most of the time, sometimes she stopped and listened to the discussion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Floyd, Sam and Tom discussed</td>
</tr>
<tr>
<td>00:55:25</td>
<td>individual presentations active again</td>
<td>Floyd continued his drawing and writing on the board</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dianna continued building Lego, stopped sometimes to listen to boys’ discussions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sam and Tom discussing</td>
</tr>
<tr>
<td>00:56:00</td>
<td></td>
<td>Floyd finished drawing and writing, joined talking with Sam and Tom</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tom left seat, started drawing and writing on the board</td>
</tr>
<tr>
<td>00:59:20</td>
<td></td>
<td>Floyd continued writing on the board</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dianna watched and talked to Floyd, then joined the presentation on the board</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sam and Tom continued their discussion and also focused on Floyd</td>
</tr>
<tr>
<td>01:05:45</td>
<td></td>
<td>Dianna started presenting her ideas though the Lego she has been building</td>
</tr>
<tr>
<td></td>
<td></td>
<td>boys listened to Dianna and joined discussion</td>
</tr>
<tr>
<td>01:21:30</td>
<td>researcher stepped in</td>
<td>researcher asked about the final product and instruct on the next reflecting session, the group presenting the final product</td>
</tr>
<tr>
<td>01:26:52</td>
<td>off-task</td>
<td>The group was reading instructions on the reflection session, then started relaxing</td>
</tr>
</tbody>
</table>
Generally, Group Banana did not really worked collaboratively and the group of four did not really formed most of the time. Table 7 indicates that the time space between each events are quite short, and it seems that there were a lot of things happening during the session. The reason was that the group of four did not really formed, thus very often, participants either formed smaller groups or were focusing on different tasks individually. At some point the group formed two sub-groups or a sub-group and two individuals, each focusing on different things, developing their small groups on different stages. Intentions to form a group of four was observed several times, but they did not really worked out.

Also, in this group, very diverse working manners and pattern were seen. Floyd tried to lead the group, after his attempt to lead failed, he decided to contribute from time to time, after he finished presenting his ideas, and he stepped back. Dianna arrived late in the room and she left the room for a while at the beginning. After she returned, Floyd helped her with the instructions. While Sam and Tom started their own discussion and were continuing it along the whole process. Dianna wanted to join the discussion of Sam and Tom at first, because it can be observed that Dianna turned her head toward Sam and Tom for a long while, but she remained quiet and did not really talked to Sam and Tom. Later, Dianna decided to work on her own, she was playing with Lego blocks. By the end, the group added up their work, and presented pretty good product.

Researcher stepped in more often in Group Banana than in other groups. While observing the group, the researcher intervened around 4 times to help regulate the collaboration, however, not all her advises were carried out by the group.

Group Banana were the only group who actually used the Lego blocks and walls with writable surface in their work and presentation, which makes their choice of tools the most creative among the three groups. Despite Lego blocks and walls, the group used the instruction sheets, iPad, scientific articles, pen and papers.
Interestingly, the observation reports were quite neutral about the group’s work. Just like the timeline suggested, Group Banana did not really worked collaboratively most of the time, but at the end, they worked collaboratively to conclude their ideas and was quite creative to present their thinking via drawing and writing on the walls.

In one of the observation reports it wrote that Tom was the key of collaboration, he was trying to build mutual understanding among the group. Sam contributed by discussing with Tom and he was the one who noticed and invited Dianna to join the discussion, when Dianna was silently listening to Sam and Tom’s discussion and expecting eye contacts. Dianna did not find a way to join the group’s discussion in a natural way, so she decided to work on her own, building Lego blocks, and wait until her turn to present came. Floyd at the very beginning introduced that he was not well, and his contribute in the group paralleled with his saying. He was contributing his ideas, obviously expect others to accept them, every time after he voiced his ideas, he stepped back and was off-task for a while. During collaborative discussions, Floyd was not really negotiable, he just voice his thinking, and expect quick result. However, the atmosphere of the group was quiet and creative, with no conflicts, even though they had difficulty forming a group of four.

Group Banana worked more in a cooperative instead of collaborative way, especially before they were preparing the presentation. Different roles and working manners were quite obvious to see. It was said in one of the observation report that the biggest challenge Group Banana faced was defining the core of the problem, and that the researcher had to step in several times to provide guidance.

4.2 Reflection by each group

In this section, video recordings and transcripts of each group’s reflection sessions will be used. At the reflection phase, instead of been separated in three rooms, all groups of participants, observers and researchers were gathered in one room, and the groups of participants was doing the reflection in front of all the rest of people and the cameras. Except for the participants, observers and researchers within the
presenting group, the reflection session was the chance for the others to have a look at the reflecting
group’s work. According to the instruction that the participants were supposed to follow, each group
would reflect on their problem-solving process. The following table lists examples of the questions
participants reflected upon:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How did you establish your group?</td>
</tr>
<tr>
<td>2</td>
<td>How did you become aware of common goal or common ground?</td>
</tr>
<tr>
<td>3</td>
<td>What strategies were important?</td>
</tr>
<tr>
<td>4</td>
<td>How did you approach the problem?</td>
</tr>
<tr>
<td>5</td>
<td>What have you learned?</td>
</tr>
<tr>
<td>6</td>
<td>Was creative collaboration manifested?</td>
</tr>
<tr>
<td>7</td>
<td>What kind of emotions did you feel?</td>
</tr>
<tr>
<td>8</td>
<td>How satisfied are you by our collaboration?</td>
</tr>
<tr>
<td>9</td>
<td>What was the main challenge, and what strategy did you use to deal with this challenge?</td>
</tr>
<tr>
<td>10</td>
<td>What materials you used?</td>
</tr>
<tr>
<td>11</td>
<td>What do you think about your interaction?</td>
</tr>
</tbody>
</table>

*Note.* The questions were designed by Vuopala, E., Hyvönen, P., & Kaisto, J., Impiö, N., in 2014, retrieved from the printed materials used in the PROMO project, 2014.

But in order to better serve my research aims, more attention were given to the following points:
first, what challenges and failures the groups were able to identify or were willing to talk about; second, according to each group, what they learned; third, whether the group used any strategies to defeat the challenges, if yes, what are the strategies. Answers to the first two questions concern about the presence
or absence of each group’s learning from failures or impasses; while the final question aims to see how the researchers evaluate the performance of each group, which will be brought to a comparison with the group’s actual problem-solving process.

4.2.1 Group Apple’s reflection

Group Apple was very expressive in their reflection, they were able to recognize and voice out their challenges and learning, however, they were not very aware of the strategies they applied to defeat the challenges and to prevent failures. But with the guidance of the researcher, the group were able to reflect their strategies. In Table 8, based on the group’s reflection, the group’s learning, challenges, and strategies are listed, SEE Table 9:

Table 9 Challenges Group Apple recognized

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Fragments of conversation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. unmotivated at the beginning in the morning and after lunch</td>
<td>M: <em>It was highly awkward.</em></td>
</tr>
<tr>
<td></td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td>P: <em>After lunch I was really tired.</em></td>
</tr>
<tr>
<td></td>
<td>All: @@@</td>
</tr>
<tr>
<td></td>
<td>L: <em>Me too, I was also tired after lunch.</em></td>
</tr>
<tr>
<td></td>
<td>P: <em>And there were few minutes that I felt like I don’t wanna be here.</em></td>
</tr>
<tr>
<td></td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td>M: <em>I think we were all prepared to put in effort I think I can stress that now that especially at the beginning I could feel that it took an effort from</em></td>
</tr>
</tbody>
</table>
each one of us to start communicating.

L, Z: umm-hum.

M: And I think it was morning and at least I was tired.

P: I, I wasn’t very motivated when we started. @@@

All: @@@

P: I didn’t think this was gonna work.

All: @@@

P: But when we started working and I think it was okay.

All: @@@

P: I don’t like mornings.

L: Yeah, I think the beginning it was really hard for everyone I think. I’m also hard to think about or communicate something.

2. physical constrain

| 2. physical constrain | M: I think it was a bit, in the end we had so small computer. I’m thinking that we have found better solution, I think it took a bit away from collaboration because of the physical constrain. |

3. annoyed by the instructions

| 3. annoyed by the instructions | M: I was a bit annoyed about the stuff we had to follow. If we were given just the task and we would be able to manage much better. |

4. problem defining the

<p>| 4. problem defining the | M: hmmm, main challenge. I think it was a bit difficult to define the core |</p>
<table>
<thead>
<tr>
<th>core problem</th>
<th>problem.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. communication challenges caused by personal differences</td>
<td>Z: Communication, because of our differences, sometimes it was difficult to communicate, even if we were thinking alike, we have to manage...</td>
</tr>
<tr>
<td>6. the task was challenging</td>
<td>L: And challenge was at the beginning, I did not know how, what kind of change for the educators and teachers after 21 years. It’s hard to think about the future.</td>
</tr>
</tbody>
</table>

Note. M=Marsha, P=Peter, L=Lynn, Z=Zoe, @@@=laughter, conversation fragments selected from different time were separated by -----.

Interestingly, the group recognized more challenges than the observer and researcher did in the observation reports and working manners analysis. The reason behind might be that in order to keep the group motivated and the emotions positive, the group members who detected challenges decided not to complain, instead, they tried to do something to cope with the challenges. As the analysis of timeline and working manners in the previous section indicated, Group Apple’s collaboration was very smooth, with nice atmosphere and positive emotions, with no conflicts occurred. Though the group said that they did not plan on anything, nor could they think of any strategies, in later part of their reflection, they recognized what contributed to their success were:

1. They were open-minded and active in discussions so that it is more possible to have some new ideas;
2. The use of pen and papers, especially the use of mind-maps helped the group to gather their ideas together, keep record of their work, focus, and crucially, it helped them to define the core problem;
3. The group have good collaboration experience already, they know what to expect from collaboration in general;
4. Reading scientific articles helped to provide more inspirations and clues, which helped the group to define the core problem and find solutions;

5. Candies helped soothing the emotions.

The group was also quite open when they share what they have learned. Different learners reflected that they learned different things, for example, in Example 1 the group shared their thinking:

Example 1: Group Apple reflecting their learning

<table>
<thead>
<tr>
<th>Peter: What did you learn?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lynn: Umm.</td>
</tr>
<tr>
<td>Peter: Anything?</td>
</tr>
<tr>
<td>Lynn: I think just for me I learn how to solve problem with more practical methods. That means that the solution is not only a pictures, it cannot be achieved in reality, but just for our solution, it can be worked in reality. I like that one.</td>
</tr>
<tr>
<td>Marsha: I also learned not to stick too much on the reality but to have an open mind, and it’s good, especially at the beginning at the brainstorming part, to...</td>
</tr>
<tr>
<td>Lynn: Yeah.</td>
</tr>
<tr>
<td>Marsha: To open as much as possible.</td>
</tr>
<tr>
<td>Lynn: And just for the educational issues, we also... I always focus on the education and teaching and learning, I do not always put science into education but today I got that ideas that we can also put science into the education.</td>
</tr>
<tr>
<td>Marsha, Peter: Yeah.</td>
</tr>
<tr>
<td>Zoe: And I think it was nice because we were different, we think different and we act differently, and even though we could manage to communicate and come up with something that is</td>
</tr>
</tbody>
</table>
To summarize, the group learned, firstly, Lynn learned how to solve problems with more practical methods; secondly, Marsha learned not to stick too much on the limitation of reality but to have an open mind; thirdly, Lynn added that it is possible to combine education and science together; finally, Zoe reflected that she learned to practice effective collaboration via respecting, accepting and appreciating the diversity of different group members. Group Apple had a very informative and meaningful reflection, in which they willingly shared their thoughts both on the positive and negative aspect of their work and the task itself. The atmosphere during the reflection was very relaxed, which can be seen in the laughter and also the relaxed style of talking among the group members. In general, Group Apple did a very good job in both the problem-solving and reflection sessions, in which they collaborated as a group, equally contributed, kept everyone motivated, defeated all the challenges, and finally produced good solutions. In case of Group Apple, their good performance stand solid in line with good learning.
4.2.2 Group Grape’s reflection

Group Grape also talked very openly in their reflection, especially they shared their thoughts on the challenges they faced. The group worked in a safe and relaxed atmosphere, in which it was very easy to share their ideas, and everybody was able to participate equally. However, as the group reflected, for a quite long period of time, the group soaked themselves in the uncertainty and confuse caused by the openness and vagueness of the task. And the uncertainty was not only about the task itself, but also about defining the core problem and about how to proceed the problem-solving process. These negative emotions can be found in Example 2:

Example 2: Negative emotions in Group Grape

Sarah: Yeah, so at the beginning it was difficult for us to figure out what we should start with, like how we should proceed but then we decided that the best way would be to read some theoretical materials and share some basic information and start discussing after that.

-----

Dany: Especially the question’s so vague.

-----

Dany: And like there’s no answer to it. So it’s just we need something to work with.

Sarah: Yeah. And then we were thinking about like the core of the problem. And for us I think it was a bit difficult to define. Maybe not difficult, but challenging.

-----

Dany: And just to clarify I don’t know if everyone else got the same question or not, but it’s not that we’re not sure of the solution, not because we did not come up with a solution. So because we don’t know if there’s a solution, we don’t necessarily know how our solution fits or bad.
The good thing was that though the negative emotions had significant effect on the group, the group were trying their best to do something and get things done. Then decided to read the articles given to them, as they assumed that the articles must be related to the core of the problem, and so that they could get more ideas from the articles. They were right in their expectation, starting from reading the articles, on which they were silent for around half an hour before the lunch break. Then after silent reading the group had open discussions and debate, on topics related but not limited to the scientific articles. It was obvious to see that the group became more focused, produced many interesting ideas. But again, just like Group Apple, Group Grape were also not aware of the strategies they applied. Instead, as in Example 3 they reflected on the merits of their work:

**Example 3: Merits of Group Grape**

Sarah: *Yeah. But also discussing those articles helped a lot.*

-----

Amber: *At the beginning when we divided, we actually don’t need strategies that much. But after that, we just discussed openly on the topic.*

-----
Dany: *Maybe that we should...initiative. Like no one told Sarah to take down notes so we were just discussing she just brought herself to do it, which is really helpful.*

-----

Dany: *And so we just have to kind of go back and think what we said. Sarah just turn around, look down.*

-----

Sarah: *Yeah I think we discussed many interesting points and it was a productive discussion. And there was this trans-activity, like we reacted, each other know what we were saying, not just one suggests and then the idea is forgotten. Like the discussion was always, it was like building on the previous ideas.*

-----

Dany: *I think everybody was treated equal. Everybody has the equal say. We all kind of spoke to the same amount I think. We all discussed the ideas.*

*Note. The talking above were selected from different part of the reflection, each are separated by ---**--.*

From the talking above the merits of Group Grape contributed to their success in collaboration and the problem-solving task are distracted:

1. Open discussions helped free brainstorming and thus made more ideas voiced and heard;
2. One of the group member volunteered to took the role as a note-taker, which helped to keep their thinking in record and organized;
3. Individual accountability enhanced the quality of their discussions;
4. Effective interactions kept everyone in the group involved in the discussion, their ideas respond to and build upon each other’s ideas;
5. Equal contribution was another factor that facilitated their collaboration.

6. Reading and discussions on the articles helped the group to become more focused.

Eventually as in Example 4 one of the group members answered that the most valuable thing she learned from this session:

**Example 4: Sarah reflecting her learning**

Sarah: *Well, in such situations, I always like to learn from other participants. Because we obviously have different points of view and different experiences. It’s always very interesting to know what the person thinks and what affected those attitudes. So that’s the most valuable thing that I learned.*

To summarize, Group Grape experienced quite some minor and major challenges, but the fatal one was the negative emotions they suffered from the openness and vagueness of the task, under the influence of which the group had difficulty reducing the fatigue, defining the core problem, and better manage the time. This situation could be explained as an systematic error which could be caused by the fact that one of the participants did not have the instruction sheets, and sharing the sheets with another participant was not a good enough solution, so the group lost a change to have someone could potentially lead the group fearlessly and determined. Or it was so that the group was so overwhelmed by the feeling that “the task is so vague” that the feeling took their attention and patience away and the group missed important points in the instruction sheets. Here a failure could be detected: Group Grape failed to find the most effective solutions to deal with the major challenge they ran into. However, Group Grape was very persevering, and managed to stop the major accelerated into a fatal one.

**4.2.3 Group Banana’s reflection**

Group Banana reflected in an inhibited manner that it seems they wanted the language milder and so that other’s feelings are kept unhurt. The atmosphere was restrained, polite yet relaxed and playful at some point, some inner jokes can be heard, see Example 5:
Example 5: example of inner jokes and laughter in Group Banana

Researcher: *There are some things like some ideas. What did you learn? You did not say.*

Floyd: *Dianna learned how to stop me.*

Dianna: *@@@ Yeah that is what I learned.*

Floyd: *How to stop Floyd and Tom!*

Dianna: *No it is not that, I said, participation.*

Note. @@ = laughter.

The group started with saying, it was easy to start communicate, they did not have any problem forming the group. As they recall, after they read about the question “How does teachers’/ educators’ role will change over the 20myears” they did not really understand the question, so they started by discussing what is the role of teachers now. Then their reflection was more about recalling their thinking back in their problem-solving session, for example how did they approached the question, what they did, and what was their solution. They avoided answering what was the main challenge at first, but later on, they expressed their emotions, both Dianna and Tom said they felt bored at first, but they were trying to do something. Then Dianna added that she felt like they could not reach any specific solution, nor was she confident that the ideas in the group could work together, she was not confident that the group could complete the task. After this they came back to answer the question “what was the main challenge”, see Example 6:

Example 6: Group Banana reflecting on the main challenge

Tom: *(reading)* what was the main challenge *(reading)*

Floyd: *Stop me to speak*
Dianna: @@ @My challenge was to make Floyd stop, just kidding @@

Tom: I think also one of the challenges are, we don’t really know, like maybe because we were not given this before, you know kind of read through and digest on things, it was kind of difficult, we are just thinking out of, we don’t have something to backward (Back work?), it is just something we just feel, it might be, we don’t know I think that was one of those challenges.

Sam: I can add, The challenge was to know when we can start, because the question also itself, or someone challenging us, this problem to solve to itself was kind of a challenge, then you started, how can you solve this one, then like 20 first minutes we were kind of confusing, not knowing where can start and looking at each other, and the researcher advised us “OK, you can read the documents and you can start”.

Tom: It is funny, I was thinking we don’t know anything about this thing and we just, we are thinking about the future in 20 years, how can you create one kind of solution for something you don’t even , you are not there yet, you don’t know how it is gonna be (reading) what strategy did we use at the time and why (reading), the strategy again, we asked questions, and we were jotting down like asking each other what we know , what we think it might be the solution, (reading)what materials did you employ (reading) I actually I read something similar to this, talking about knowledge society, I think we came about citing somebody about it, like this man talking about what we should be expecting in the near future like that so, his name is Castell. (Reading) how do you describe interaction at that moment (reading) Interaction was good? Was it?

Floyd: Aha (negating) because you...

Tom: It was not?

Floyd: It was awful.

Tom and Sam: @@@
At this point we could see that the group recalled that the first challenge was that the task itself was very vague and challenging: it would be hard to come up with solutions to what does not exist yet. However, later Floyd was saying something, but was stopped by Dianna. I believe from here we could see that the video recording was disturbing the group’s reflection, as I could tell that Dianna was redirecting the conversation when Floyd was about to say something improper.

Just like the other two groups, Group Banana was also not aware of their strategies, they said, they did not plan or anything, they just started discussion. Though till now it seems that Group Banana had poor work, but they actually produced fun and creative final results: Floyd, Sam and Tom drew and wrote on the white boards, especially Floyd, his illustration of ideas as a tree, with leaves and roots was a key of the group’s collaboration, finally started near the end of the problem-solving process, when everyone was expressing his or her ideas to complete the “tree”. Despite the diagrams, Dianna used Lego blocks to present her ideas, adding more points to the whole presentation.

Note. @@@=laughter, words and sentences in “( )” are researcher and observer’s in-text notes in the transcript.
In general the reflection of Group Bananas was inhibited: they reflected more about their strengths and products than the challenges and complaints, which I believe have two reasons: firstly they wanted to protect each other’s feelings; second, they were influenced by the video recording or the camera.

Group Banana failed to recognize or were not willing to express the main challenge they experienced: difficulty forming a group of four, nor did they took effective efforts to tackle this challenge, for example trying to motivate group members and trying to build a group. Instead, they worked in their own ways: each of them contribute to the task either in smaller groups or individually, then at the end they added up their works, and finally they were also able to present good final product, which was actually quite nice and creative.

4.3 Conclusions

My research intentions stemmed from a situation when transcribing the data I was surprised to realize that when I was an observer and later as a researcher, I came up with total different evaluations of three groups of participants’ work in the research sessions: what I believed to be failure was actually not failure, what I thought to be successful was not really successful. This situation shocked me and I could not help thinking as an educator and learner, faced with unreliable evaluations, also I started to doubt why we judge students by failure and success, and I wonder what exactly are we evaluating, learning or performance, or both?

But evaluation and assessment was only the beginning of my exploration of research intentions. I realized that instead of designing a fair and reliable enough assessment strategy, what really grasped my attentions was the “fake” failures, which shared some of the features of productive failure (Kapur, 2008; Kapur & Bielaczyc, 2012; Kapur & Rummel, 2012; Kapur, 2014) and was the issue I wanted to have a closer look at, and I believed that a constructive perception of failure is the idea I wanted to stress in my research.
Every section of the theoretical framework and the literature review was presented for a reason. To build and support my research intentions, literature searching and reviewing were carried out with clear directions: I wanted to explore in existing literature I could find answers concerning the following issues: is it possible that productive and constructive learning can be in the situation of failure, and how failure could facilitate learning. Literature on productive failure (PF) first caught my attention, because I found PF explained my doubt and that the articles explained how and why failures can be productive under certain circumstances, for example loose instructions, ill-designed tasks, and delayed instructions (Kapur, 2008; Kapur & Bielaczyc, 2012; Kapur & Rummel, 2012; Kapur, 2014). However, different than the PF contexts, in which students were designed intentionally to fail in their tasks, my research was describing failures which occurred in a natural way. Though situated differently than my research, theories of PF provided an essential theoretical support to my studies. Then gradually, more literature concerning my research intentions was found and reviewed, eventually they were organized in a way that formed the logic of my studies and thus my literature review was organized and presented.

And the literature review acted as the spine of further data analysis. I analyzed my data in the lenses of theoretical framework and earlier studies I collected and discussed in the literature review. For example in my analysis, collaborative learning was also one of the aspect I looked at: for example, with the definition of collaborative learning (Weinberger, 2014; O’Donnell & Hmelo-Silver, 2013) and characteristics of effective collaboration (O’Donnell & Hmelo-Silver, 2013; Johnson D.W. & Johnson R. T., 1987; Johnson, D. W., Johnson, R. T., & Smith, 1989; Vuopala, 2013) born in mind, I paid extra attention to aspects such as group formation, individual accountability, interaction, etc., which acted as lenses and criteria for me to describe and analyze the working manners of each group of participants. Also with the understanding that learning and performance needed to be distinguished (Kapur, 2008, E. L. Bjork & R. A. Bjork, 2011), I redesigned my analysis methods, research questions, hypothesis and format of final presentations. Despite having based my research design and analysis methods on these theories, I found my research questions, hypothesis and results tightly connected with the theoretic framework
though due to the limitations of my research design and data how exactly my participants learned from failure is open to future studies. But the literature review section on failure in learning and learning from failure bridged this gap: possibilities and mechanism of failure-enhanced learning were introduced and explored with the help of existing literature. Instead of focusing on how exactly was the process of my participants if they learned from their failure, I had different research questions focusing on different collaboration working manners and learning results. My original first hypothesis was that, poor or good performance does not always indicate the failure or success in learning; and the second was that students could learn from failures. With same focuses, I had three research questions:

1. How did each group worked? How was the collaboration? Especially were there challenges or failures? How did each group deal with the challenges they faced?

2. How did each group reflect about their collaboration? Were they able to define the challenges, failures and strategies?

3. What did each group reflected about their learning from the session?

At this stage, after analyzing the working sequences, timelines, and reflections, I am confident to see that my data is good enough, because all those three groups had diverse yet meaningful working processes and styles, which were worth analyzing and were able to support my research, thus my research questions were answered, my hypotheses were tested and improved afterwards. Concluding the previous sections, the conclusion section is also a good opportunity to make comparisons of the three groups of participants horizontally, I start with answering the research questions.

\[ \textit{RQ 1: How did each group worked? How was the collaboration? Especially were there challenges or failures? How did each group deal with the challenges they faced?} \]

From the timelines, observation reports, and \textit{Figure 3} we could see that Group Apple, Group Grape and Group Banana experienced different problem-solving situations, in which they all had different working manners and styles of collaboration.
Figure 3. Comparing three groups’ different working manners.

Group Apple was the group that had the smoothest collaboration among the three groups. They formed the group and started performing very fast. Everyone was contributing in the collaboration, everyone’s ideas were voiced and heard. Despite collaboration skills, they also had good time-managing skills, which allowed them to follow the instruction, steadily develop their work and finally presented well-structured final results.

After Group Apple is Group Grape, who had quite nice but not as smooth work. Group Grape became productive after the lunch break, when they started fruitful discussions, before which they were mainly complaining the vague task description and they spent half an hour silently reading. Group Grape’s discussion showed critical thinking, and had deep thoughts. Unlike Group Apple, who concluded their ideas and presented their final product to the camera, Group Grape did not collaboratively conclude anything or presented their product in the end, instead, one of the group member volunteered and took the role as the note-taker, who was taking notes and concluding the group’s ideas.
Then Group Banana had quite a bumpy and less active group work. If the metaphor is that the problem-solving process is a road from the starting point to the destination, Group Banana split into sub groups, each exploring different branches of the road, then they met up near the end, reached the destination together. Group Banana was the only group used Lego blocks and illustration on white board in their discussion and final presentation, which was creative and interesting.

From the perspective as an observer and researcher, both challenges and failures could be observed from the data. Two common challenges all groups experienced were firstly, at the beginning the atmosphere was too awkward and not relaxed to start working, and secondly the task itself was challenging because of its openness and vagueness. No other major challenges were observed in Group Apple, but Group Grape experienced difficulty making sense of the task and time-management issues, especially before the lunch break. Group grape also had difficulty understanding and following the instructions. The major challenge that Group Banana faced was collaboration: most of the time a group of four did not really form, sub-groups existed, or even sometimes individuals were focusing on different tasks: instead collaboration, Group Banana worked more in a cooperative way.

**RQ 2: How did each group reflect about their collaboration? Were they able to define the challenges, failures and strategies?**

Though some of the challenges and failures could be observed from the video recordings, some of them could only be felt by participants themselves. When it comes to challenges and failures, Group Apple reflected more challenges than researchers recognized in the observation, which indicated that members in Group Apple may intentionally or unintentionally chose to keep some personal negative emotions in their own mind, thus to keep the group motivated. Group Apple did good job recognizing and tackling challenges, thus successfully prevented any challenges or errors accelerate into failures.

Group Grape were also able to recognize their challenges, yet did not find proper solution to the challenges efficiently, and that it was easy to be observed that the group was overwhelmed by the
negative emotions, which influenced their actual working manners and time managing. The good point was that even though Group Grape was unmotivated, they had a “let’s at least do something” attitude, which pushed them to make effort to continue the collaboration, and finally they found the core problem and produced very good discussions, in which all participants had equal say. Group Grape succeeded in completing the task, though the process was not that well-balanced. The challenge from the main challenge, the ambiguity of the task was partly solved, but there could be better solutions, for example, reading the instruction more carefully, thus have a better understanding of the task description.

Compared with Group Apple and Group Grape, Group Banana had a less open reflection. They were mainly talking about their approaches to the problem and solution than challenges, though from the timeline and observation reports more than one challenge could be detected, for example we could see that Group Banana definitely experienced difficulty forming a group of four. The uncertainty of the task was also a challenge to Group Banana. Group Apple and Group Grape though faced with challenges, tried to form a group of four and keep the collaboration going. Group Banana applied different strategy: they split up and each sub group or individual focused on different tasks, the explanation of which can be found in previous analysis sections. Disagreement of different working styles among the group members could cause this situation, though no obvious verbal conflicts or argument were observed.

Interestingly, it is worth mentioning that in the reflection sessions, which was the first opportunity for the participants, researchers and observers from other groups to see the work done by a certain group, Group Apple seemed to have a nice collaboration and also product; Group Grape had more negative emotions, and the final solution was good but could be further improved; while Group Banana had very interesting presentation and good final solution. If we evaluate the groups merely based on this reflection session, probably Group Banana would be evaluated the best of the three groups. However, after our knowledge of the works of all the three groups from multiple perspectives, we know that this evaluation was not proper.
RQ 3: What did each group reflected about their learning from the session?

Groups reflected different learning. Group Apple really talked a lot of learning, the Group Grape talked less about this issue, and then when it came to Group Banana, they did not really answer this question. So comparing the three groups in general, we could see that all of the research questions finds their answers and the hypothesis are tested and improved.

All the three groups experienced different ways of working in groups, Group Apple and Group Grape were collaborating while Group Banana was more like collaborating. Similar but different challenges occurred in the three groups’ work, while they acted differently. Group Apple tried to motivate the group and kept the discussions organized and as fluent as possible; Group Grape had more negative feelings of the task, they were unmotivated and complaining a lot but they were adjusting their emotions all the time, gradually they had fruitful discussions and good final results; Group Banana did not verbally shown any negative emotions or conflicts but they failed to form a group and had to split the group, in the end, due to good individual accountability, the group had good results. The learning reflected by each group were also different.

As a result I would improve my hypothesis:

1. Poor or good performance does not always indicate the failure or success in learning, a full picture of both the process and results can offer a more complete understanding of how learners learned; for example, it is possible that a group with satisfactory academic performance or final presentation may actually have poor learning, while a lower-performing group may experience better learning though they had poorer performance or final presentation;

2. Students could learn from challenges or failures, but those who are more aware of the challenges, and faced the challenges with more positive emotions and good problem-solving strategies could learn more from failure and the process of finding proper solutions to the challenges, and are more possible to tackle challenges and thus avoid them accelerating into failures.
What is also important to stress is that, based on both my research data and my personal experience, the skills of learning from failure is not an automatically or magical built-in function of learners, it takes practice, training and learning to finally acquire and master. Also, as the analysis and results suggests, putting aside the learning and performance, all groups experienced challenges and failures, but what made the differences was the attitude, commitment to the task, and actual contribution of learners.
5 GENERAL DISCUSSIONS

5.1 Validity, reliability and limitations

Despite the findings above, the research and analyzing processes also taught me practical knowledge and experiences, of which the most important is that, never take anything for granted, be prepared to diversities and changes. Concerning the research itself, I learned that even though I have found solid theoretical foundation to build my research upon, in the actual data, very diverse working manners could be observed, not all of them worked as they were supposed or assumed.

To self-evaluate my research, validity and reliability are two important criteria, Brink (1993) concluded that:

A valid study should demonstrate what actually exists and a valid instrument or measure should actually measure what it is supposed to measure. Reliability is concerned with the consistency, stability and repeatability of the informant’s accounts as well as the investigators’ ability to collect and record information accurately. (Brink, 1993, pp. 35)

As a researcher, I could only follow the ethical principles and try my best to describe and analyze based on the reality of my data. In general, my analysis of the data was done in a descriptive and narrative voice, by which I was trying to be as objective and unbiased as possible, bearing in mind that I have limitations; meanwhile especially in the literature review I tried to collect previous literature which are both suitable and significant to support my studies.

Even though carefully designed, tested and ethically carried out, the research had constrains and limitations, which were possible risks that could affect the reliability and reliability of my research. The first limitation was physical constrains, a factor which worried me the most: especially from the data collected from the reflection by Group Banana, it was obvious to notice that the video recording was intruding the validity and accuracy of the data: some groups avoided to reflect the negative aspects of
their collaboration because they are aware that everything was recorded. This situation posts a problem and challenge to video researches: how to minimize the intruding effect of cameras or video-recording itself in video data collection and researches?

The next point I want to stress is about structuring. I noticed that even though all the participants have good theoretical knowledge and understanding of what is collaborative learning and the importance of instructions, not all of them are following the instructions given to them, which led to confusions, misunderstandings or unwanted and unexpected difficulties in their problem-solving process. This may due to their different personal and group working styles, however, how to design an ideal instruction that can be actually carried out and followed by students is also another meaningful research topic. This also concerns the flexibility of scripts, which was slightly mentioned in my thesis but not deeply studied here.

The final limitation was a small sample of participants, which is low both in size and diversity especially in case of educational background, which made my research and results contextual. To summarize, if future researches on similar topic will be carried out, it is important to take it into consideration during both the research design and analysis stages that my research results could be influenced by factors listed above. I am confident to say that my research results are reliable given the context of my research design and analysis. But if future researchers would repeat my research using similar research design and analysis methods, except for that they would select different participants, it would be possible that they would receive different results in their studies.

5.2 Implications and possibilities of future studies

One of the most important implications and also what motivated me to conduct this research is to spread a constructive attitude toward failures and mistakes, thus failures and mistakes are taken the most advantage of, and thus future and even worse mistakes or failures could be avoided or weakened.

This could be applied not only to students in school years, nor limited to individual persons, but could also be practical and beneficial to a larger scale: a country or a society. For example, when I was
almost finishing analyzing my data, a devastating blast happened in Tianjin, China, caused hundreds of deaths. By then my social media were full of prayers and tears, while there were very few posts on why the blast happened, how to retrieve the responsibilities and how to deal with current situation and how to prevent similar failures in the future. I was sad, angry, and worried, yet I was hoping that if the whole society had the belief that failures, though as devastating and deadly as this one could be, can shed light on us, and that if failure already happened, instead of grieving and regretting, we cannot just pretend the tragedy did not happen, what is more helpful is to face the failure, and make effort to stop it accelerating, and prevent future failures.

Either with similar topics, research design or exact same data, it possible for me and other researchers to conduct meaningful studies: there are so many things could be looked at and researched in learning situations. For example, in the general discussions section I came up with some questions for future researchers:

1. How to design a flexible and informative enough instruction that benefit learners the most?
2. How to minimize the influence of video recording on participants and collect as natural data as possible?

These questions could be seen as had emerged from the flaws and risks of my research, but coming back to the research topic itself, there is also much to be done by future researchers. For example, from a critical yet constructive view, if we want to encourage people not to think failures as bad, disadvantageous, or malign (Gartmeier et al., 2008), does that suggest that failures are good things and people can sit there and be positive, thinking, everything will be alright, after all, failure is supposed to be good?

The question above seems awkward, because my instinct tells me it is not how “learning from failure” works; and that my instinct also tells me, both being overly optimistic or pessimistic do not help solve the problem, defeat the challenges and prevent future failures, instead, being able to analyze and learn from challenges and failures is the key. Or perhaps to “normalize” (Schwartz, 2015) failure and
mistakes is a better way to say it? But in academic world, instinct is not strong enough to lead to a scientific conclusion. Due to the fact that I could not and am not able to conclude everything I wanted to study in this article, it would be practical to leave the task to future research as well.

Finally, if I base the next research interest on the belief that people can learn to learn from failure and that failure does not only play an important role in formal learning, but also informal learning and dealing with everyday life in general, I came up with a new direction of research: what benefits could people who are able to learn from failure exactly receive? For example in their life later than school years, for example career life and family life? I believe that learning from failure is a multi-disciplinary issue, which reaches not only field of education, but even psychology, sociology, and cognitive science.

5.3 Ethical issues

One of the important ethical principles of scientific researches is to “treat participants and the data with value, dignity, respect and confidentiality” (Corbin & Strauss, 2014, pp. 29). In my studies, all participants took part in the research sessions were informed before the sessions that their behaviors would all be recorded for further analysis. The data including video recordings, transcripts and observation reports were kept only available among the research group members. To protect personal information and privacy of participants, they were given pseudonyms in the analysis process and also the presentation of research results. The data were used for no other purposes than PROMO researches.

Proper referencing skills were practiced in the studies to avoid plagiarism and self-plagiarism. To develop and strengthen my arguments, various literature from other researchers were borrowed and referenced. The data was collected, analyzed and kept safe ethically.
REFERENCES


