The Role of Children's Emotions during Design-based Learning Activity

A Case Study at a Dutch High School

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Abstract: Design-based learning (DBL) is attracting increasing attention for its potential to support informal learning, and as a way to enhance science and technology education at schools. However, related research has not yet considered the emotions children experience during DBL and how these affect the learning process. We report a case study aimed at developing a deeper understanding of children's emotional experience during DBL. In total 9 children (12-13 years old) are involved in this case study. In order to assess children's emotions during DBL lessons we used a self-reporting non-verbal instrument (the emotion card, which adapted from Five Degrees of Happiness Smiley Face Likert) and a verbal instrument (the Geneva Emotion Wheel Questionnaire, which contains 16 emotions). In addition, a group interview probed into the role of children's emotion during DBL. We discuss the methodological challenges exposed in this study, which will need to be addressed in future studies regarding the measurement of children's emotions in DBL.

1 INTRODUCTION

Design-based Learning (DBL), Learning-by-Design, and Learning through Design are related approaches to learning that apply the tenets of Design Thinking (Rowe, 1987) in a problem or project-based learning context. In general, DBL involves open exploration, learning from trial and error, reflection, teamwork and supportive tools. Following the growing trend of computer supported education, DBL increasingly employs technology-based tools, e.g, Scratch, Littlebits, LEGO education kits, and MakeyMakey etc., to support its design and learning process.

It is well known in education research that emotion plays a vital role in the learning process. Firstly, emotion is known to affect student's effort, motivation and commitment to their academic works (Skinner et al., 2014). Secondly, emotion can trigger student's recall of memories and influence on student's cognitive evaluation of events or memories (Efklides and Volet, 2005). Emotion is also deemed to modify the choice of learning strategies and the level of self-regulation in learning (Pekrun, 2014).

Accordingly, for DBL activities, emotions play a big part both as an outcome (e.g., in the case of successes or failures, or of group based interactions),

as well as a factor that influences learning. Nevertheless, some characteristics of DBL, in contrast to traditional education, may lead to distinct emotions and consequent impacts on the learning process. For example, student may frequently experience failure when building and testing their prototypes or design ideas. However, rather than resulting in a negative emotion (e.g. disappointed or anxiety, etc.), such an episode may generate curiosity, excitement, or being motivated to explore new design solutions. Consequently, the effect of such an episode on their learning process could turn out to be positive.

This research sets out to understand such emotional facets of DBL when integrated into formal education for children. As is known, school is a major part of children's life where emotions can be very vivit: children are often evaluated; they experience friendship, belonging, but they may also have negative interactions with other children.

To this point, little is known about the interplay between children's emotions and DBL from existing literature. We engage in an exploratory case study where we pose one central research question (Q0): What is the role of children's emotions during DBL? This was addressed in three sub-questions:

Q1: How do children undergo emotions during

DBL activity?

Q2: How do DBL activities affect children emotions?

Q3: How do children's emotion influence their DBL activity?

These questions are addressed in the context of a case study, where a DBL activity was introduced in a classroom with children aged 12-13. The setup and methodologies used in this paper aim to contribute to research on engaging children in DBL in the future. Furthermore, with the understanding of children's emotions in this context, this paper will generate insights for research on developing affective interventions for the process and research on improving DBL experience.

2 RELATED WORK

There is currently an increasing research interest in approaches to learning that are described as, DBL (Nelson, 2004), Learning-by-Design (Kolodner, 2002), or Learning through Design (Resnick and Stephen, 1990). As a pedagogical approach, all these interchangeable terms have been shown to make a positive contribution to motivation and learning performance. Researches even have been conducted to describe the main characteristics of DBL, including characteristics for organizing DBL in higher engineering education (Puente et al., 2013) and for teaching children digital literacy (Bekker et al., 2015).

On the whole, related research demonstrated that DBL can have a positive effect on children's learning activity. Research reported by Giannakos et al. (2014) demonstrates that enjoyment had no effect on students' intention to participate in similar DBL activities in the future, while happiness had a positive effect and anxiety had a negative effect.

In the following sub-sections, we clarify the context of this research (see section 2.1), describe the groups of emotion in learning addressed by literature (see section 2.2) and summarize existing measurements for tracking emotion (see section 2.3).

2.1 DBL Characteristics

In order to deepen the multilayered understanding of a DBL activity, and also ensure the external validity of the study, we settled on a list of criteria that DBL should match via synthesizing DBL characteristics from previous relevant studies. The structure of these criteria follows the framework of the curricular spider web (Van den Akker et al., 2010). These are detailed below.

1) The characteristic of *Learning Activity*, which is framed with four aspects: It is open-ended and has enough flexibility, with an authentic context and real-life scenarios; with multidisciplinary knowledge and skills; and with a design process.

2) The characteristic of *Teacher Role* is that teacher acts as a coach who enables the student to become an active learner.

3) The characteristic of *Grouping*, which is made up of two aspects: children should share a sense of responsibility; and are expected to communicate and collaborate with peers and stakeholders.

4) The characteristic of *Materials and Resource*, which is composed of two aspects: using hands-on materials and resources for prototyping or testing and using minds-on materials and resources for empathizing, defining or ideating.

In conclusion, the above four characteristics will all run throughout the case study reported in this paper.

2.2 Emotions in Learning

In the introduction section, we already emphasized the importance of considering emotion under the learning context. But what emotions are frequently triggered in a general learning context? Pekrun's (2014) research on student's emotions and learning does not target at a specific age group, but proposed four groups of academic emotions especially relevant for students' learning: Achievement, Epistemic, Topic and Social emotions.

In short, Pekrun's taxonomy of learning emotion provides a macro guidance, which can be potentially used for qualitative analysis of emotion data in a DBL context.

2.3 Measuring Emotion

Measuring emotions during DBL brings theoretical and practical challenges, because the nature of emotion is complex. The knowledge that guides the study of emotions will also influence data collection and interpretation (Rienties and Rivers, 2014). But after all, tracking learner's emotion as an approach to learning analytics offers an opportunity for educational stakeholders and researchers for understanding and improving the learning experience (Rienties and Rivers, 2014).

In the sub-sections below, we extract from the literature several emotion data gathering approaches,

which we believe can be applicable to measuring emotions in DBL.

2.3.1 Self-report Measures

In general, one advantage of self-reports is that they can help collect emotion data that cannot be observed directly. Researchers can obtain such data from respondents at relatively low cost, e.g. using paper-and-pen rating scale surveys, questionnaire sand interviews etc. The disadvantage of self-reports is also that sometimes data collected by them is biased or unreliable.

Rating scales are widely applied to obtain self-reports. Examples that could be completed by children are the verbal self-report instrument -- Geneva Emotion Wheel (Scherer, 2005), and the non-verbal self-reports -- Self-Assessment Manikin (Bradley and Lang, 1994), and Five Degrees of Happiness Smiley Face Likert (Hall et al., 2016). With regard to Geneva Emotion Wheel (GEW), it was developed to measure respondent's experiences (Scherer et al., 2013) in diverse contexts, which may include learning. The Self-Assessment Manikin, a pictorial assessment, is widely applied also for the purpose of measuring learner's emotions. A Smiley Face Likert (SFL) scale named the Five Degrees of Happiness is a child-centred instrument mainly for measuring emotional reactions in child computer interaction.

On the other hand, Subtle Stone (Balaam et al., 2010) is a technical and tangible instrument for children aged 12 to 13. It allows children self-report seven emotions in the classroom in real-time.

Questionnaires are also a popular self-report measurement for a learning context, e.g., the Achievement Emotions Questionnaire (Pekrun et al., 2011). It was designed precisely for assessing adult learner's achievement emotion.

2.3.2 Measures Other than Self-report

Non self-report measurements can be used instead of self-report measures where these are difficult to obtain or where they might introduce bias. They can be used together with self-report for triangulation purposes to gain a multifaceted understanding of children's emotions or to check the reliability of self-reports. However, these methods are more time-consuming than self-reports (Encyclopedia.com., 2008). Such instruments may be various:

Language processing is a form of measurement for detecting learner's emotion in text. Linguistic Inquiry and Word Count (Pennebaker et al., 2015) is one of the examples.

Computer recognition of facial expression is another form of measurement, e.g. using the Facial Action Coding System (Ekman and Rosenberg, 1997), and Facial Expression Analysis Tool (Kaiser and Wehrle, 2001).

3 METHOD

For the external validity of our study, we ensured that the main characteristics of DBL would be included in the lesson plan for the study. We constructed a DBL lesson plan, spanning a two-week period for a total of 100 minutes of classroom time. In total 9 children aged 12 to 13 involved in this study, while some of them were involved in the first DBL lesson and some in the second DBL (see Table 1.). A team of two researchers acted as facilitators in the classroom and collected data through two emotion instruments (described in more detail in section 3.2), audio recordings and video recordings.

3.1 Task

In this study, all children worked in pairs and were given the design challenge: "to design a school experience for your partner". This learning activity was designed after a d.school (Hasso Plattner institute of Design at Stanford) course assignment about redesigning the gift-giving experience for their partner, and was embedded into our DBL framework. DBL materials and resources in this study included the d.school crash course workbook, and both new (e.g. LEGO education kits, Littlebits.) and traditional (e.g. clay, color papers, tapes, etc.) materials.

The procedure of two sequential DBL lessons in our case study is adapted from the design thinking process proposed by d.school (see Figure 1, the colorful blocks are set up by d.school while the grey blocks are added by us). Apart from two warming-up sessions (i.e. team building and introduction), in total six main DBL sessions were carried out in order.

In addition to taking part in these DBL activities, children used two instruments to report their emotions during DBL. Then, we conducted a follow-up group interview at the end of the second lesson. See milestones of this activity in Figure 1. At the end of the activity we offered a gift to children to thank them for their participation.

3.2 Measures
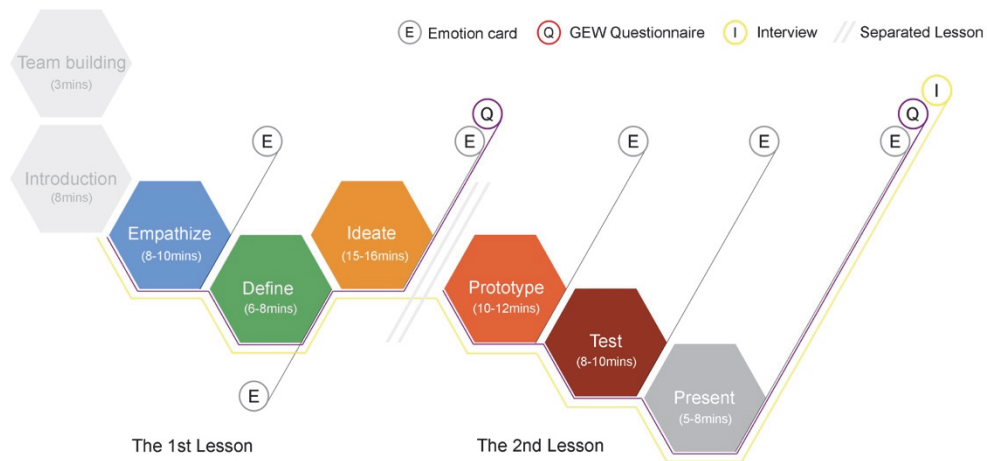
In this study, we focused on self-report instrument

Figure 1: DBL procedure in this study (adapted from the design thinking process of d.school.

on account of its superiority on measuring children's subjective experience of their own feelings and behaviors, but also for its efficiency.

We devised an emotion card based on the Five Degrees of Happiness SFL, a simple non-verbal self-report instrument which they could complete efficiently during the DBL. We also used a follow-up verbal self-report instrument (i.e. GEW questionnaire), with which children are able to express their emotions freely. Although some previous studies already applied GEW in the field of learning, it has not been applied in the DBL context before. Moreover, we also used for the first time emotion cards based on Five degrees of Happiness SFL under the context of DBL.

3.2.1 Emotion Card

In order that the card looks attractive to fill and easy to understand, we adapted Five Degrees of Happiness SFL (Hall et al., 2016). We used it for evaluating children's event emotion before the end of each session, as shown in Figure 2. At the end of each session, they were required to circle one among 5-pointing scale to report their overall feeling.
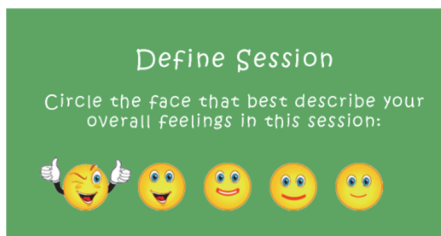

Figure 2: Example of emotion card in this study.

Researchers handed out and collected emotion cards after every single session. Emotion cards from all 6 sessions were collected (see Figure 1.): Empathize, Define, Ideate, Prototype, Test, and Present.

3.2.2 GEW Questionnaire

There are two reasons for embedding the Geneva Emotion Wheel (GEW) into our questionnaire: First, the emotion families in GEW cover almost all emotions, representing the dimensions of valence and control/power respectively; Second, participants are not required to recall any vocabulary to describe their emotional experience, but only asked to identify an experienced or imagined emotion among the various options provided (Scherer et al., 2013).

We made some adaptations for using this instrument with children. We chose to decrease the number of intensity degrees from four in the GEW
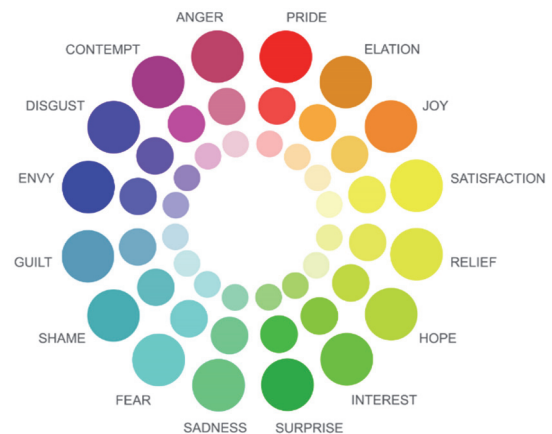

Figure 3: Adapted GEW version 1.0 in this study.

version 1.0 (Scherer, 2005) into three levels (see Figure 3), in order to decrease the complexity of distinguishing intensity differences for children. Furthermore, we combined this adapted GEW version 1.0 with an open-ended question as supplementary for examining children's emotions and experience during DBL activities.

3.2.3 Group Interview with Children

In the end, researchers used a face-to-face group interview. In the phase of the interview, questions concerning their answers on the emotion cards and questionnaires were asked. We held two parallel group interviews among two groups by two researchers under the guideline of a group interview protocol.

4 RESULTS

The central research question (Q0) and three sub research questions (Q1, Q2, Q3) are in both quantitative and qualitative results. The answer to Q1 is linked to section 4.1.1 and 4.2.2, Q2 can be found in section 4.2.1, and Q3 is explained in section 4.2.3. With respect to Q0, section 4.1.2 where presenting the changes of children's emotion state during DBL, is a supplementary part on the basis of the answer to Q1, Q2, and Q3. The data collection process includes the emotion card survey, the GEW questionnaires, interviews, observations, documents, and audio-visual materials. In order to ensure anonymity of the materials the children would deliver, every child was assigned with an avatar which they used to 'sign' their work and the emotion questionnaires they completed.

4.1 Quantitative Results

The quantitative data sources come from emotion card survey and the GEW part in the questionnaire.

4.1.1 Undergoing Emotions

Children selected between 1 and 5 emotions and used only 7 of the 16 categories in the GEW. Most of the children undergo joy, and some of them undergo elation, pride, satisfaction, and a few of children undergo surprise, while only one child experienced shame and another child experienced anger during DBL. Among these selected emotions, most (5/7) locate in the positive quadrant, except for shame and anger. In the meanwhile, most of (5/7) these emotions

locate in the high control quadrant, except for shame and surprise.

Within two DBL lessons, a total of 13 valid responses (8 in the 1st lesson, 5 in the 2nd lesson) from the GEW questionnaire were collected. Since children selected between 1 and 5 emotions, these 13 pieces of valid responses amount to 33 'votes' in 7 different emotions. See details in Table 1. Participants participating in both lessons are in shaded cells. The abbreviations and marks in Table 1 and Table 2 are interpreted as: Jo (Joy), Sh (Shame), Su (Surprise), Pr (Pride), El (Elation), An (Angry), Sa (Satisfaction); + (high intensity), * (medium intensity), - (low intensity).

Table 1: 13 pieces of GEW questionnaire in two DBL lessons.

Participant	In the first lesson	In the second lesson
Mickey	Jo+	Jo+
Minnie	Jo+	Jo+
Donald	Jo+, Sh-	N/A
Daisy	Jo+, Su+	N/A
Winnie	Pr+, El*, An+	N/A
Piglet	Jo+, Pr*, El+	N/A
Bambi	Jo+, Pr+, El+	Jo+, Pr+, El+, Sa+
Thumper	Jo+, Pr+, El+	Jo+, Pr+, El+, Sa+, Su+
Simba	N/A	Jo+, Pr+, El+, Sa+

4.1.2 Changes of Emotion during DBL

We quantified the scales in our emotion card as a value ranging from 1 to 5 according to the degree of happiness. Based on that, a descriptive statistic result is presented in Table 2. This result includes 24 valid responses from 8 participants involving in the session of Empathize, Define, and Ideate, and 15 valid responses from 5 participants involving in the session of Prototype, Test, and Present.

Table 2: Descriptive statistic result: 39 pieces of emotion card.

Session	mean	sd	IQR	n
Empathize	3.9	1.5	2.00	8
Define	4.6	0.5	1.00	8
Ideate	4.8	0.5	0.25	8
Prototype	5.0	0.0	0.00	5
Test	5.0	0.0	0.00	5
Present	5.0	0.0	0.00	5

However, only 4 participants have taken part in the entire six DBL sessions, while the remaining participants were absent from some sessions for some personal reasons (e.g. sick leave, etc.). In order to probe their emotion changes during an entire DBL unit, we only analyzed the data of emotion changes over six sessions from aforementioned 4 participants. The curve of emotion changes displays as the Figure 4 below. As is seen, all participants reported the highest degree of happiness as from taking part in the prototype session and all the sessions after the prototype session. These curves showed a broad tendency of rising.
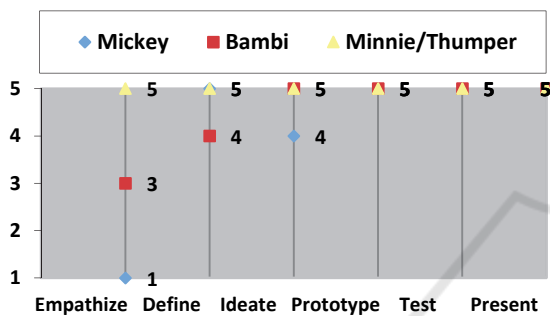

Figure 4: Emotion values from 4 participants.

4.2 Qualitative Results

The comments collected through the open questions and during the group interview were transcribed and analysed thematically by the first author. Three major following themes emerged which are discussed below.

4.2.1 Affective Elements in DBL

Considering the curriculum components framework (Van den Akker et al., 2010), our data suggest that some components of this framework have a positive effect on children's emotions during DBL. For instance, children were affected by the DBL content. Some children think the subject in the Empathize session was interesting, while others did not feel excited at all by it. Some children were less interested in the subject in the Ideation session. Secondly, the DBL learning activity also affected children. Almost all children reported that the Prototyping session was their favourite one. Some children liked drawing their design idea and some were fond of showing their design project to others. Thirdly, the role of DBL facilitator/teacher proved to have a positive effect. A supportive facilitator made children feel joy; this finding is in line with the expectation in (Penuel et al.,

2016) that children's enjoyment increases with the teacher's ability to help them connect lessons to the unit challenge in DBL. Fourthly, the grouping component in DBL also affected them. Children considered working with friends makes them feel joy in line with earlier studies (Carroll et al., 2010; Giannakos and Jaccheri, 2013) that suggested that enjoyment is enhanced when working with peers. Fifth, the DBL material and resources had an affective impact. For instance, LEGO bricks which some children used to build their prototype made them feel good. This statement resonates with (Barak and Doppelt, 1999) who concluded that LEGO is a factor making children feel curious presented in the previous studies.

Finally, the time setting caused a negative emotional response: children found that starting at 4 p.m. as we did was too late and were not happy about it.

4.2.2 Emotions in DBL

Children reported several emotions using the verbal instrument: the emotion of joy, elation, pride, satisfaction, surprise, shame, and anger. Due to lack explanation by the children about the experience of feeling shame and anger, we would not discuss the emotion of shame further in this paper. Hence, we only classified the rest of 5 emotions into the taxonomy (see section 2.2) of academic emotion proposed by (Pekrun, 2014) for a further discussion.

First, pride was a prominent achievement emotion. Most children were proud of their own ideas, their drawings, and prototypes. Some children felt pride in themselves and even in their partner when receiving the design solution form their partner. Second, in the epistemic emotion theme, feelings of surprise were highlighted. Some children were surprised when they performed better than they had expected on tasks, while one child realized with a feeling of a surprise this lesson was much more fun than she thought. Third, on the topic emotion theme, the feelings of satisfaction, joy, and elation were prominent. Compared to an earlier study (Hugerat, 2016) which assessed the extent of student satisfaction and enjoyment while carrying out scientific tasks, our study found that children not only feel satisfaction with the DBL lessons but were in a state of elation towards DBL activities. Moreover, the materials and resources used in class also made them feel joy. Forth, in the social emotion theme, the feelings of joy were highlighted. Children tend to feel joy to work with friends, as was expected based on earlier research (Carroll et al., 2010; Giannakos et al.,

2014). The supportiveness from their facilitator is another source of joy feelings, in line with (Hugerat, 2016).

4.2.3 Effect of Emotion on DBL

Our findings from the interview regarding how emotions influence their attitude or behaviors in DBL are synthesized into two major aspects: First, Mickey and Minnie state that joy facilitates their learning outcomes during the heads-in sessions, while it has no effect on their hands-on sessions. Second, Bambi, Thumper and Simba state that pride and elation have a positive influence on their DBL activities. Similarly an earlier study (Giannakos and Jaccheri, 2013) found that enjoyment has no effect on students' intention to participate in similar activities in the future.

5 DISCUSSION

Emotion plays a vital role in DBL activities, acting as a reciprocal linkage between antecedents (the affective elements in DBL) and effects (the effect of emotion on DBL). Five DBL components and seven emotions are highlighted in this study.

The findings reported are only tentative, since this has been but a small-scale study and we experienced some serious methodological challenges in assessing children's emotions during DBL. First, data collected may suffer from a social desirability bias, where children tend to only report positive emotions in order to appear more appealing to researchers (Hall et al., 2016). Second, it has not been possible to track emotions throughout the DBL activity using a self-reporting instrument as this would have interrupted the flow of their learning experience to some extent.

This study has derived some useful insights, which will guide our future research on measuring children's emotions during DBL activity: Firstly, negative emotions need to be fully embedded into the emotion measurement instrument in order to detect the full range of emotions. Secondly, to ensure the credibility and reliability of emotion data, future study designs should aim to ensure that children do not share their emotion responses with each other during the data collection process. Furthermore, due to the subjectivity of asking the subjects about their opinion on their own emotions, future studies could triangulate subjective report data with facial expression analysis and observation during the entire DBL activity. Lastly, a pre-and-post test of children's emotional states is necessary, since except for academic emotions, emotions originating from extraneous activities and factors outside of school may also influence children's learning performance.

6 CONCLUSIONS

This paper argues for the importance of considering emotions in DBL. An exploratory case study where children aged 12 to 13 engage in DBL in a classroom was conducted where we assessed their emotions. Our results show that from the children's point of view, positive emotions such as pride and elation seem to have a positive effect on their engagement during DBL, while joy seems to facilitate their engagement just before coming up with a design idea. Further research will replicate and extend these results to a broader range of situations where emotions could play a role in DBL (e.g., cases of failure, negotiation, and conflict), and at the same time especially pay attention to measuring children's emotion without interrupting the flow of DBL. In addition, further research may also pay attention to adding the emotional angle of learning to existing computer supported DBL tools.

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