ReflectionScope: Scaffold Students to Articulate Reflection during Design-based Learning Processes

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Abstract: Supporting students to make their reflections visible and accessible during the inquiry-based process can enhance the learning outcomes and foster reflective thinking. This research examines how technology can play a role in scaffolding students to create contextualized reflection-in-action products which can contribute to reflection-on-action in design-based learning classroom. In this paper, we present the design of a multimedia tool called ReflectionScope, which offers contextualized scaffolding to prompt students to monitor their action and create reflective videos using the digital video-camera or visual "scope" attached. Twenty-one secondary school students (aged 13) used ReflectionScope in a two-weeks design-based learning class. An analysis of the reflective video's students created during this class and the post-interview, shows that students articulate their reflection-in-action in a structured way with context-rich information. Students perceived that the videos are beneficial for retrieving and understanding the contextual reflection-in-action moments for reflection-on-action. Based on our findings, we propose design principles that can contribute to designing for reflection practices which can be enhanced by media-technology in real-world inquiry-based learning environments.

1 INTRODUCTION

Design-based learning (DBL) is an inquiry-based form of pedagogy that engages students in a design thinking process to do project-like work (De Vries, 2006; Ke, 2014). Students engage in a self-directed learning process (Loyens, Magda and Rikers, 2008) including successive authentic inquiry and design activities. Learning takes place while the learner is actively engaged with a realistic instructional context. Supporting students to be reflective during the learning process and articulate their reflection can enhance students' learning outcomes from the learning processes (Linn, 2000).

Prior research has employed varied media to promote learners' intentional creation of digital traces during the learning process (Tseng, 2015; Gourlet *et al.*, 2016; Leinonen *et al.*, 2016). Yet, these tools often fall short in scaffolding students' explicit and context-rich reflection articulation. This paper explores how to design media technology that can scaffold students' (aged 13) contextualized *reflection-in-action articulation.* We aim to support students to create effective *reflection products* in the design-based learning environment, where learning activities are self-directed and take place in the real world instead of in a learning simulation environment. To reach this goal, we designed and evaluated a system named "ReflectionScope". It can support students to record context-rich reflection videos during the learning process. Furthermore, the videos can help students retrieve their learning experience sufficiently and collectively. 21 secondary school students used ReflectionScope for a two-weeks Design-based learning project. We conducted a post-interview session comprising of 1) recalling their experience of the moments when students used ReflectionScope to record reflection-in-action, 2) a simulated reflection-on-action session where students watched peer's reflection videos and described how they might retrieve information from these reflective videos.

The contribution of the paper is three empirically derived design principles for the design of media tools to support secondary school students' reflection in design-based learning classrooms.

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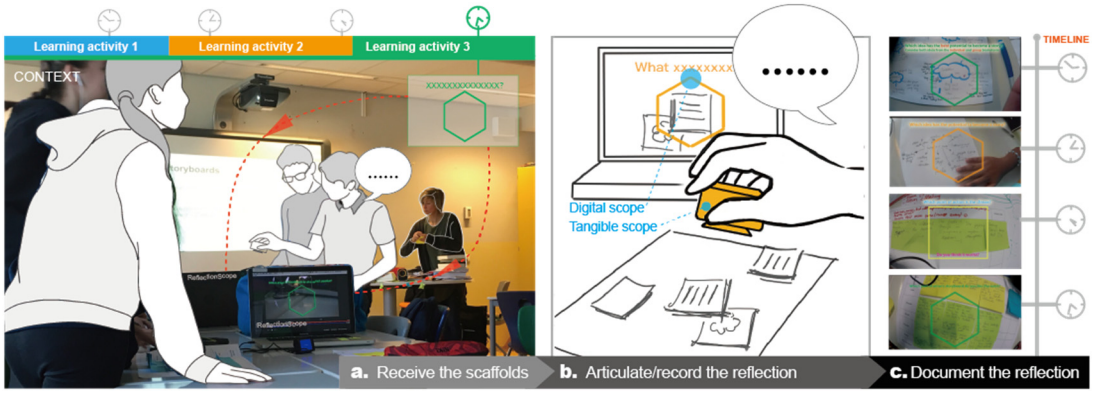

Figure 1: a) the mechanism of releasing the contextualized scaffolding (recording interfaces) to students' devices; (b) tangible scope linked with the digital scope overlay; (c) the way of documenting and visualizing of the reflective videos.

2 RELATED WORK

Regarding technological reflection suppport, Fessel et al. distinguished between technologies for two types of reflection, i.e. reflection-in-action guidance and reflection-on-action guidance (Fessl *et al.*, 2017). The first type promotes learners to reflect in the midst of the operative learning activity, while the second type supports reflection-on-action to engage learners in reflecting at a later time with respect to the learning activity. *Prompting* is a crucial technique to motivate learners to reflect in the midst of doing (Fessl *et al.*, 2017).

What to prompt can have a major influence on the efficiency of learning (Davis, 2003). For younger students who lack the ability to reflect appropriately, more directed prompts need to be offered for several reasons: 1) To direct attention to important contextual issues (Self *et al.*, 2000), 2) to activate tacit/inert knowledge (Garcia *et al.*, 2018), 3) to help learners to make justified decision (Davis and Linn, 2000), 4) to enhance awareness of the learning strategies (Verpoorten and Westera, 2016). Regarding the more directed or content-specific prompts, they need to reduce reflection difficulties to lower the cognitive load. Typically, there are built-in reflection opportunities embedded in learning simulation systems. For example, the system may present text-based prompts which appear along the process of learning. *Reflection breaks* is a technique for embedding stop-and-think moments in the learning flow; eLearning platforms distribute reflection moments evenly during the learning process (Verpoorten and Westera, 2016).

Presenting prompts close to the time the learner needs them is more effective (Thillmann *et al.*, 2009). However, few prior studies setting in *real-world* inquiry-based learning environments have realized the *built-in* reflection opportunities. Technological support for reflection-in-action support has been attempted, but the support was mostly confined to prompting students to intentionally monitor the progress. "Spin" (Tseng, 2015) is a tool for students to document their physical design projects through capturing and creating animations during the design process. Similar to "Spin," "Research diary" is a photography tool within a studio space in the classroom. It promotes students to capture the progress of their 'making' project by taking pictures (Gourlet, Eveillard and Dervieux, 2016). "Teamup" (Leinonen *et al.*, 2016) is a tool, with generic reflection prompts "what we did," "what we will do" and "what is your design progress," to prompt students to video record their oral reflection. In this setting where all the learning activities take place in the real world, as they present the prompt in a static way, the teacher might need to continuously remind students to use the tool to keep track of the learning process. Such tools might be further improved by paying more attention to how to make the prompts present dynamically.

Media-enhanced reflection-in-action can also help to retrieve learning experiences after a longer period of time. According to experimental learning theory, learning takes place through reflection on hands-on doing (Kolb, 2014). The learning process needs to be documented in a way that enables to revisit effectively. In most of the studies conducted in real-world classrooms, where they support students to document all these reflective products on the timeline, students can trace back their learning process chronologically and reflect on the critical incidents of the learning processes. "Spin", "research diary", and "team up" present a chronological process

overview of the photos or videos created along the learning process. (Tseng, 2015; Gourlet, Eveillard and Dervieux, 2016; Leinonen *et al.*, 2016). Moreover, Boud et al. suggested that in order to be able to return sufficiently to learning experiences, context information is important to capture (Boud, Keogh and Walker, 1996). In a learning simulation environment, Lin et al. proposed the design strategy of displaying problem-solving and thinking processes to enable learners return to the experience (Lin *et al.*, 1999). However, in a learning setting in which most learning activities take place in the real world, the context information can only be traced back by learners intentionally capturing the context information during the learning process. Fess et al. introduced specific contextualization components of reflection guidance to prompt for manual text input of the context descriptions. They emphasize the importance of capturing context-rich information when reflecting, which enables the individual to recall sufficiently (Fessl *et al.*, 2017). Their setting is informal learning in the workplace. However, this scaffolding strategy is not suitable in our setting. In our setting, design-based learning classrooms: although reflection is an important learning activity, reflection-in-action occurs in parallel with the main DBL activities. Students cannot be interrupted too much from their learning flow. Text-based input is not suitable in such a situation. Video and audio are faster to verbalize reflection-in-action. Garcia et al. designed a gamified smartwatch app with a content-specific (science concept) reflection prompt. It encourages students to be aware of the phenomena in nature that can be explained by a learned science concept. Students can record audio reflections when they find a natural phenomenon that can be explained by a learned science concept in nature (Garcia *et al.*, 2018). The technological tools describe above aim to support young learners to generate reflection fast and conveniently which includes authentic contexts information.

Most related research has been carried out in learning stimulation environments in which the learning activities and prompts can be integrated and well-programmed. In that case, the prompt can pop up actively at pre-set moments. The learning context can be automatically documented by the system. The design strategies cannot directly be transferred to a real-world design-based learning setting. The built-in reflection opportunities are not easy to embed in the learning processes where the learning activities take place in a real-world environment. Moreover, the context information of reflection moments cannot easily be tracked automatically outside of a learning stimulation environment. It requires learners to capture it intentionally and at the right moment.

When extensive explanation is provided to the student by the teacher on diverse considerations when engaging in reflection, such as how to determine when to reflect, on what to reflect and the requirements about the format and the length of the reflection, there is a risk of cognitive overload of the student. Furthermore, in an educational setting, learning often happens within a learning community, Lin et al proposed that the forum for reflection is important design strategy (Lin *et al.*, 1999). The representation of reflection is required to be prepared to fit in the social characteristic of the learning community. This in turn also requires reflection representations to be retrieved efficiently by others in this learning community. If the recorded reflection is lengthy and less to the point, there is a risk on information overload of the teachers and students.

Considering our interest to develop tools to support reflection in and on action, so far, less effort has been invested in understanding how to design for creating reflection-in-action products that can be retrieved effectively in a learning community. Within a DBL context, the challenge in technological reflection scaffolding is to direct students' contextualized thinking and recording with a fairly low cognitive load and limited interruption during the learning process. We set out to design media tools for supporting reflection in the context of a design-based learning context. By examining the applicability of the design strategies employed in related works to our context, three challenges emerge:

- How to embed reflection opportunities and prompts that can scaffold and guide students' reflection-in-action in the context of flexible DBL processes?
- How to support students to articulate reflection-in-action in a context-rich and structured way without spending too much effort?
- How can reflection videos help students retrieve learning experiences in context efficiently and collectively later in time?

3 PROPOSED DESIGN PRINCIPLES

We propose three design principles on how to design multimedia tools that can support teenager's reflection in a design-based learning context.

3.1 Design Principle 1: Embed the Reflection Opportunities

P1: Enables the Teacher to Present the Preset Contextual Reflective Prompts on Students' Recording Devices to Ensure that They Get the Prompts Timely in Relevant Contexts.
The content-specific prompt can give students a focus on what to reflect, and it only makes sense in its relevant context (Davis and Linn, 2000; Sharma and Hannafin, 2007). Delivering the content-specific prompt at the relevant time constitutes the concept of actively displaying the prompts. Unlike learning simulations in which all the learning context and the corresponding reflection prompts can be integrated and well-programmed, DBL environment is more flexible, the teacher plays important role in scaffolding students, thereby, the system should enable teacher's manipulation of what to prompt, and when to prompt. In addition, we set out to leverage the visual properties of Augmented Reality (AR) technology. It displays the reflection prompts on the recording interface in order to draw students' attention.

3.2 Design Principle 2: Contextualize the Recording

P2: Offers a Flexible Camera Perspective with Visual Focus to Support Contextualized and Structured Recording.
In order to minimize the interruption to students' learning flow, the system should allow students to intuitively identify a structured way to interact with the tool. In design-based learning classrooms, where a variety of representations (such as paper-based sketches, CAD models) are created during the learning process, a fixed camera perspective is not suitable. Therefore, a flexible camera perspective should be offered to get access to all these representations. A content-specific reflection prompt aims to give students a focus for thinking, as mentioned above, to cooperate with the prompts and to make the recording products in a structured manner. The recording interface should give a visual focus to support students in making the connection between thinking and the visual recording.

3.3 Design Principle 3: Reference for Retrieving the Reflection Product

P3: Attaches a Contextual Element as a Reference for People to Decode the Reflection Product.
People create extra representations to help them make sense of situations (Kirsh, 2010). An extra representation attached to a reflection product could provide a persistent element as a shared reference to help people decode information captured in the reflection products. In order to offer a reference to help others to understand reflection-in-action moments sufficiently, we propose that the contextualized scaffolding is valuable to benefit others to understand the reflection products. Furthermore, adding extra elements to the video can also be beneficial for the learner him/herself to recall the reflection moment after a long time.

4 ReflectionScope

The general idea of ReflectionScope is to design a tool dedicated to reflection in DBL classroom. It is a quick video recording system whose recording interface can be visually augmented. The basic recording interfaces for students are overlaid with the digital "scope," which comprises of the teacher's reflective question input and the shape element (Figure 2).

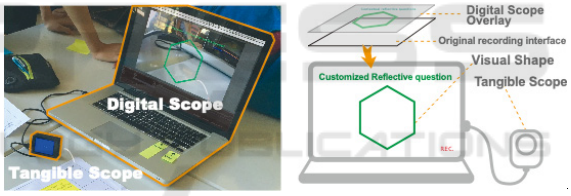

Figure 2: The set-up and components of ReflectionScope.

The scaffolding mechanism enables the teacher to input the reflective questions and embeds them in the learning process by setting the time when the questions should appear for students to answer. The system will convert the reflective questions into ReflectionScope recording interfaces, which will be automatically released to students' devices at the preset time during the process (refer to Figure 1. a). Students can only record video up to 60 seconds at most for each question, but they are allowed to record several videos by using any interface. ReflectionScope embodies the three design principles as follows:

P1. It includes two design elements. First, the system enables students to receive the scaffolds only when they need it during the DBL process. i.e., the system releases the recording interface at a preset time when is the moment that teacher anchored for student to think contextualized about the knowledge application, learning strategy, or thoughtful on action.

Second, the scaffolds are presented as the colorful digital overlays on top of the recording interfaces. It shows the question in the context, yet they can easily be discriminated from the context of the real-world artifacts. When the interfaces are released on their devices, the students' devices change from a blank screen to ReflectionScope interface to draw their attention.

P2. We designed the digital scope overlay. The digital scope consists of the reflective question with a shape linked to it. The tangible "scope" (the video capture tool) is designed to accompany the digital "scope". This form of design is to tell students that they need to use the tangible scope in hand to target the real-world artifacts and they can show the contextual evidence within the digital scope on the screen (see Figure1. b).

P3. Apart from documenting the videos in a chronological order, ReflectionScope can automatically document the videos with the digital scope attached to help people understand the behaviors revealed in the videos (refer to Figure 1. c). In addition, the system constrains every video duration within 60 seconds, to limit the whole length of videos within an accessible range to watch.

We have evaluated ReflectionScope to address the following research questions:

- How can ReflectionScope direct students contextualized reflection-in-action articulation
- How can ReflectionScope support students to capture the context information in a structured way with lower cognitive load.
- How can the reflection videos help students retrieve the learning experience collectively and effectively after a longer period of time?

5 METHOD

In this study, we employed a research through design method (Zimmerman, Forlizzi and Evenson, 2007). Through evaluating ReflectionScope, we aim to contribute an empirically examined knowledge of how to design the technology-enhanced tool for students in DBL classroom or any other similar learning environment.

5.1 Procedure and Participants

Our study was conducted in a two-weeks language acquisition class of a local international school. These two classes of students have learned the knowledge of writing scripts. The specific learning project was to design an original script. Students not only created their own script and they also played the role of audience to look at each other's works. Before the class, the teacher planned and created six contextual reflective questions and embedded them into the processes including brainstorm, group discussion, creating storyboard, classroom gallery, and giving feedback for students during the learning process (refer to Figure 3). The system converted the questions into the digital scope overlay and released the recording interfaces to students' devices at the planned time. Twenty-one secondary school students from two classes (aged 13, 9 girls and 11 boys) participated in this study. They sat in pairs or triples in the classroom. Before each class, students' groups could choose to use ReflectionScope or not. Then the volunteered groups would be equipped with ReflectionScope. During the two-weeks DBL project, students worked on three sessions.

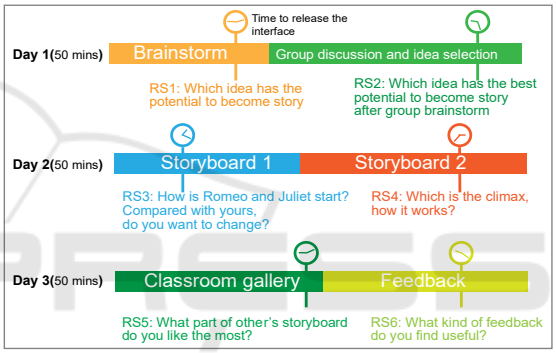

Figure 3: The DBL process and the anchored reflection moments procedure.

Session 1 (week 1-day 1): the students began to draw mind-maps to list all their ideas and discuss with the group member. The two ReflectionScope interfaces were released for scaffolding students to reflect on the possibilities of all their ideas and their selection of idea (see figure 3, day 1).

Session 2 (week 1-day 2): The students began to develop their story by creating a storyboard. Two ReflectionScope interfaces were released for scaffolding students to reflect on how they apply content knowledge to the development of their idea (see figure 3, day 2).

Session 3 (week 2-day 3): students looked at each other's storyboard and gave feedback. Two ReflectionScope interfaces were released to scaffold students to learn from peers and accommodate feedback (see figure 3, day 3).

Post-interview (week 2-day4). After these three sessions, 15 students were engaged in the post-interview session.

5.2 Data Collection and Analysis

Since one function of ReflectionScope is capturing reflection-in-action through video recording, in this study, we collected two types of data. The first part of data is the reflective videos that students created during the whole learning process. The second type of data is from the semi-structured interview with the students. We analyzed the video data to reveal how students performed in the reflection practice with the intervention of ReflectionScope. The interview data was analyzed to and combined with the findings of the reflective videos.

5.2.1 Reflective Videos

Students' reflective videos were saved with the digital overlay and documented chronologically in specialized folders of their own devices. This part of data was transcribed and analyzed in MAXQDA (Oliveira *et al.*, 2013). Our analysis of students' reflection videos followed the method of (Smith, 2016). By examining the information from different layers of the videos, we aimed to find out the emerging students-tool interaction process (see figure 4). We coded the structure of the verbal content. Then the videos were coded interactively by thoroughly examining what they were talking about and the interaction emerged in the video. Third, two coders discussed the interpretations of the verbal content.

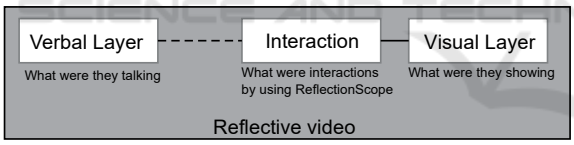

Figure 4: Video coding structure.

5.2.2 Semi-structured Group Interview

After the students have used ReflectionScope for two weeks (three classes in total), we interviewed 15 (separated into four groups, 8 girls and 7 boys) of them. Interview sessions included two parts. First, students were asked to recall the moment when they used ReflectionScope during the learning process. To help them recall, we gave them the interfaces they had used during the whole process. Second, students watched an integrated video created by ReflectionScope (in chronological order with the overlay tagged) that showed the whole process of a student, to simulate the activity of peer reviewing for reflection-on-action. In this part, each group watched another group's video, and where then asked them how they could make sense of the videos. The interviews were audio-recorded and transcribed verbatim.

6 FINDINGS

In the end, we collected 56 intact videos to analyze. Students had created 79 videos in total. But on day 1, something went wrong with one of the devices that resulted in 17 videos (belong to four students) being without the soundtrack. But these mute videos can be counted to calculate the rate of students' completion. Not every student used every interface to record reflective videos. Figure 5 shows the average completion rate per day of two classes.

6.1 How Can ReflectionScope Direct Students' Contextualized Reflection-in-Action Articulation?

According to the coding structure in figure 4, we employed the verbal layer of the reflective videos for answering the first research question. First, we report the findings from analyzing students' reflective videos. Then we report students' perceptions to confirm what we have found by analyzing the videos.

Figure 5: The completion status.

6.1.1 Promote Students to Develop Contextualized Verbal Explanations

Through analysing the verbal part of student-creat videos, six main types of verbal articulation were coded (see Table 1).

Table 1: Components of verbal articulation.

Components of verbal articulation in the Reflective short videos (Total videos n=56)	Count of videos
Brief answer to the reflective questions	n=47 (84%)
Further explanation	n=38 (68%)
Assessment (Positive/negative)	n=15 (27%)
Proposal for ongoing action	n=6 (11%)
Repeat the question on screen	n=8 (14%)
Introducing the background	n=6 (11%)

In most of the reflective videos (84%), students had given a brief answer to the reflective questions. Following the brief answer, 38 of them (68%) contained further explanations. 27% of the videos contained either positive or negative assessment.

We further analyzed the explanations. The explanations could be described by 9 types (see Figure 6). We will elaborate on these within an example classroom scenario. In class 1, students generated some ideas in the brainstorm part: the teacher asked students to draw a mind-map to show their ideas and check the possibilities of all their ideas. To prohibit students to jump to a superficial way of idea selection, the teacher scripted two reflection moments in ReflectionScope for students to reflect on their selection of ideas. Therefore, students' short reflective videos of class 1 showed that the majority of their explanations were "referring to their personal feeling" (n=5), "their assessment on the difficulty of each idea" (n=4) and "relevant real-life experience" (n=5). A large amount of the explanation came out to be the "explanation with comparing different ideas" (n=9).

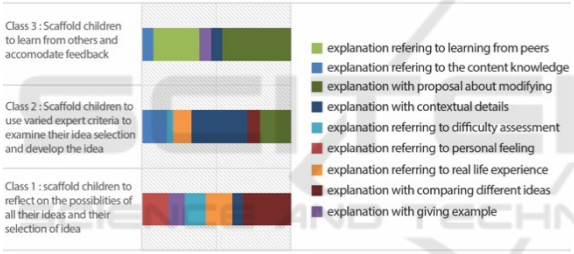

Figure 6: The changes of explanations along the progress.

In class 2, students were asked to develop their final idea and make a storyboard. The teacher scripted two reflection moments for students to reflect on some expert criteria to make them improve their storyboard. In their short reflective video, a new explanation appeared that is the "explanation referring content knowledge" (n=4). Among all these explanations emerged in this class, the "explanation with the contextual details" came out to be the most (n=9). We could see students' ideas development through thinking of more details about the selected idea. In this stage, they started to talk about how to modify their ongoing action, e.g., "I need to add more specific details (storyboard)," "I should add emotion in between (character's emotion changes)."

In class 3, the classroom activity was a peer reviewing activity. Students were asked to walk around the classroom to look at each other's storyboards and give feedback. The teacher set two reflection moments for students to reflect on their gaining by looking at the other students' storyboards and accommodating peer's feedback. The "explanation about learning from peers" appeared (n=4). "Proposal about modifying" their ongoing action becomes the most frequent type of explanation (n=6).

In conclusion, the reflective videos appeared to have the structure that students give a brief answer to the reflective question. Then most of them would add explanations. The explanations emerged from each class change in accordance with the changing of real learning context. In this case, the teacher had not inputted the questions to force them to explain (refer to figure 4), yet most of the students (78%) explained a bit for enriching the answers. Their reflection tended to be built on the contextual information as they continuously proceeded to different learning phases.

The way of ReflectionScope released the contextual reflective question can be the stimulus, which triggers students to think of the questions and give brief answers to these different questions. Then they develop further explanation by examining their knowledge in the situation to talk about how they built up the answers.

6.1.2 Students' Perception

Students' verbal explanation closely related the embodiments of P1. To verify the insights from the reflective videos, we analyzed students' comments on their perceived scaffolding.

Students perceived that they received the contextual reflective questions timely. Students reported that it is "*applicable for the situation*" and "*good questions to answer in the situation.*" It could help them "*change perspective*" and "*finalize the idea.*" The scaffolds were not always there; students could get access to the scaffolds at the teacher's scripted time. This mechanism made students feel like they were guided to "*stay on track*" since they thought these contextual reflective questions were "*good*" and "*applicable*" to answer along with their learning. However, it may make students assess the difficulties of the reflective questions before recording. Some students preferred to answer the ones that they perceived easier. Two students explicitly expressed that they chose to use the interfaces which they thought were easy ones to record the reflective videos. Because they believed that they could record better videos with the easy ones. It could explain the reason for not every student responding to each recording interface.

The reflective questions were visually situated in the context. Students considered that the visual presented, reflective question overlaid by the recording interface, supported them to "*stay on topic*" while they were recording the reflective videos. They could always see what the question was while recording. Some students thought that the visual elements "shape" the visibility of the reflective questions. Especially when the question blended with their real-world texts.

In summary, the contextual scaffolds can draw students' attention and trigger them to think of the questions in the context. While they were recording the videos, the digital scope supported them to stay on topic. Receiving the ReflectionScope interfaces set by the teacher, made students have the feeling of timeliness and they were staying on track. Some students gave up recording some interfaces that they thought hard to answer. Because they thought the videos will be shown to others and might be related to their final grades.

6.2 How Can ReflectionScope Support Students to Capture the Context-rich Information in a Structured Way with Lower Cognitive Load?

To answer this question, we coded students' interaction with their real-world artifacts while they were talking in the videos.

6.2.1 Scaffold Students to Reflect with the Visual Context Information of What They Are Doing in Hand

The purpose of the visual "scope" is triggering targeted interaction. We coded the movement which created interaction with the visual scope as one main category. We defined it as "interactive targeted recording behavior," which includes "zoom in," "focus," and "locate." This category emerged in 63% of all the videos. With these interactions, we can see the visual part in the real-world that corresponded the verbal reflection. In the videos, this visual part was highlighted within the digital scope area (see figure 6). The movements shown in the videos can also reveal students' thinking paths. e.g., were they talking a general topic (focus)? Were they going deep into a specific idea (zoom in)? Or were they talking from one idea to the other one (locate)?

Table 2: Recording behaviors.

The categories of interaction	Recording behaviors	Counts of frequency
C1: Interactive targeted recording behavior (n=35/ 63%)	Zoom in	N=32
	Focus	N=30
	Locate	N=22
C2: Targeting behavior	Pen or finger to point	N=20
C3: Untargeted behavior	Give the bird's-eye view	N=20
	Put the camera aside	N=14

Some students used a pen or finger to point the part that they were talking about. We defined this kind of behaviors as "targeting behavior," since there were not clear interactions with the visual shape on the screen, students resorted to other objects to target. The third category of recording behaviors, "untargeted behavior," are different from the previous two categories because students hold the tangible scope to give a bird's-eye's view of their real-world artifacts, or they put the camera aside without showing anything meaningful. It does not mean that students who show untargeted behaviors cannot use the tool appropriately. By checking what they were talking about, we found parts of the untargeted behaviors emerged when students were talking about something which was not shown in the real-world.

Figure 7: The interactive targeting recording behaviors.

6.2.2 Students' Perception

P2 addressed the form of scaffolds employed in a tool that can enhance students to capture context-rich information intuitively. P2 embodies in the tangible scope cooperating the digital scope of ReflectionScope. From students' reflective videos, the "scope" overlay accompanying the tangible scope shaped students' recording behaviors that they connected thinking with the real-world artifacts. Students' perception further confirmed how they identify a structured way to record the reflection intuitively.

Students reported that the digital scope informed them a way of recording with a specific structure

which they need to involve their thinking and doing simultaneously. Students reported that the way of recording made them "*go into the moment,*" "*think with more details*" and "*think what you are doing.*" One student said: "*(the question with the visual shape) they don't make sense on their own, but if you put them all together (digital scope), it actually works a lot better.*"

ReflectionScope can guide students to record reflection in a structured way without spending too much extra cognitive effort. Since one student said "*for me the most important is the visuals, because visuals help me remember more easily, for example, there is a graph, it shows me how to do it better than like a big paragraph, I don't really remember that.*" Student(S-A8) perceived that the "shape" attached to the reflective question plays a role in informing him to add explanations.

6.3 How Can the Reflective Videos Help Students Retrieve the Learning Experience Collectively and Effectively?

Our third goal is to evaluate if the reflective videos, which were created by using ReflectionScope along with the process, are efficient to look back collectively. This is aligned with examining the design principle 3.

P3 suggests the system should document and visualize the reflection product in an accessible way. The system saves students' reflection videos not only in chronological order but also the digital "scope" attached to the videos (see figure 1. c). Four groups of students watched an integrated video comprising all the videos created through the learning process by one of their classmates. Then they talked about how they make sense of the videos. We cluster three dimensions to elaborate on the students perceived efficiency of the reflective video.

The first dimension is that the videos revealed the factual information of the situation. Students recorded their verbal reflection accompanying the contextual situation. When the other students watched the video, the interaction of multimedia layers delivered rich and genuine information. Their intuitive feelings are that this way of reflection can "*see the person's thinking in situation*" and "*deeper than writing.*"

The second dimension is that the videos were structured and clear to understand what was going on with the "scope" overlay. To be precise, students reported the question element of the "scope" could help them understand the topic of the reflective videos. The "shape" element of the "scope" can support them to focus and locate where was the visual part that the learner of the video was talking. Students felt the video was "*clear and structured*" to understand. One student report how they consider the digital scope attached: "*because you have the colors and shapes, and you don't have that when you are just listening to something. It is sort of like a code, and it is like being able to use some symbols to recognize what you mean.*" While students were using the ReflectionScope to record reflection-in-action, the tool could shape their recording behaviors. As a result, when others watched one's videos with the reference of the digital scope overlay, the videos were easy to understand.

The third dimension of efficiency is that the reflective videos enabled students to qualify the learning process more easily. Students mentioned they could "*see the idea development and trace back to the idea root,*" and "*how the learner revised their ideas.*" They understood why the learner creates the videos which can be the evidence to show the learning process to others. We would like to quote one student words about how they look back at the videos: "*you can look back what you have done, what you can improve what you did wrong, you can keep on doing what you did right. And also, when you need to do your evaluation, you can look back, and you can see actually what you did instead of trying to figure out what you did, you actually know what you did.*" Students' perceptions showed that the reflective videos created by ReflectionScope have the potential to support students' transformative learning in Design-Based Learning.

Video recording offers rich and genuine information in the situation. With the digital scope attached, the videos seemed well structured to watch. Students could see how exactly the idea developed along the learning process. ReflectionScope depicts an efficient way to create reflection products that can help students understand the learning process and qualify the learning process.

7 DISCUSSION

The mechanism of ReflectionScope provides contextualized prompts which encompass both what to present and when to prompt students' reflection. Our findings showed that this mechanism could support the teacher in providing specific prompts to students actively, which allowed students to record context-rich reflections with ease. Students could develop contextualized explanations when they articulate reflection-in-action. For students aged

around 13, their reflection-in-action process tends to generate strategies of completing the task quickly or of simple self-assessment (Davis, 2003; Thillmann *et al.*, 2009). ReflectionScope plays a vital role in directing them to go beyond the routine way of thinking in school and guide towards the appropriate form of reflecting in action. ReflectionScope showed them a way of timely answering the reflective questions in related situations. In this manner, students felt they were staying on track. Moreover, they could have several reflective videos that documented the vital moments of their Design-based learning process.

In design-based learning classrooms, students are engaged in self-directed learning processes (Loyens, Magda and Rikers, 2008). The teacher's role is converted to that of a facilitator. Although the teacher's role is changed, his or her control of the classroom can also ensure learning effectiveness and quality. Our study may contribute to the understanding of how a technological tool can facilitate the teacher's role of supporting young students' reflection-in-action.

The second design principle, of employing video as the reflection representation, provides a structured way to capture the context-rich information. The digital scope (the question and the shape) cooperating with the tangible scope (the camera) provides a flexible perspective and structured way of capturing context-rich information, i.e. the visually recording of the real-world artifact links to their verbalization of reflective thinking. ReflectionScope can engage students in a quick and small reflection-in-action practice which can run in parallel to the main DBL activities. Without appropriate tools, such kind of reflection moments during the process might distract students too much from their learning flow. The result showed that it can impact students' recording behaviors to a more organized manner with less interruption to the learning flow. When students began to verbalize reflective thinking, they focused on the visual evidences related to what they had done. ReflectionScope documented the reflection moments in chronological order with the digital scope overlay. This mechanism of visualizing has proved to provide easy access to the information of the videos. Because the digital scope included a reflective question and a visual shape, it gave the audience a topic and a focus on how to decode the reflective videos. With context-rich information, ReflectionScope enables students to trace back to see the authentic learning situations. The reflective videos created by ReflectionScope are prepared for benefiting students' transformative learning which requires deliberate observation based on the documenting of learning process(Kolb, 2014).

The conventional way of teacher's scaffolding of reflection usually takes the form of dialogues in the classroom with many students(Lewis, 2017; Kolstø, 2018). Therefore, the scaffolds cannot be consistent and balanced for every student. ReflectionScope depicts an image of how to enhance students' experience of scaffolding. What we examined was the added value that technology can provide within a physical inquiry learning environment. ReflectionScope incorporated the teacher's customized input of reflective questions. It has shown tentative potential to optimize communication in such a learning environment.

The limitation of this study is that we only collaborated with one teacher and her two classes. This DBL class only lasted two weeks, of four sessions in total (three courses with ReflectionScope). As we have not well developed the teacher's input system, yet, the generating of ReflectionScope interfaces currently needs the assistance of the researcher. Future work can involve the teacher to examine the classroom communication processes through the system's intervention in a long-term Design-based learning project.

8 CONCLUSIONS

This study examined how to support students' reflection-in-action in a Design-based learning classroom. We designed and evaluated ReflectionScope to test the proposed design principles. Our findings show that ReflectionScope can scaffold students to articulate their reflection-in-action in a contextualized way while connecting their thinking with real-world artifacts. The reflection products enable students to make sense of the learning process. Our study shows examined design principles on how to design a multimedia tool that can support students to articulate reflection-in-action in an appropriate form and creating collectively accessible reflection products. We contribute the scaffolding framework and related design principles to design for scaffolding students' reflection articulation.

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