An Interactional Ethnographic Approach to Understanding the Design of Student Learning in a Self-Directed STEM Class

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Abstract: This study aims at exploring the dynamic in self-directed learning (SDL). It examines how uncertainties are caused by pedagogy oriented by the SDL process and how students overcome uncertainties. A qualitative case study was conducted on a group of fourth graders in a self-directed STEM lesson. The STEM lesson was designed by a team of teachers from a school supported by a university-school partnership project. Data sources included videos on classroom observation, teacher interviews, student focus group interviews and artifacts generated for learning. The STEM lesson was analyzed with the scholarship of interactional ethnography. The case analysis makes visible how uncertainties and student learning emerge in the SDL process. This study contributes to explicating why uncertainties are needed for promoting SDL and how uncertainties are dynamically shaped by and shape learning contexts. Student agency is realized in this dynamic. The findings inform the science of designing learning for promoting SDL.

Keywords: interactional ethnography, self-directed learning, STEM education, uncertainty

Introduction

Educators around the world have affirmed the need for developing ability of self-directed learning (SDL) among young learners (e.g. Bolhuis, 2003; Hew, et al., 2016; Tan, et al., 2011). Teachers are challenged with questions about how to design learning in order to promote SDL among students. SDL embodies both processes of learning and the development of self-direction as learners' attributes (Brockett and Hiemstra, 2018). Experiencing the autonomous processes of SDL is a way to cultivate the attribute of self-direction. This experience of autonomous processes relates to the design of learning contexts (Hew, et al., 2016). Yet, it is difficult to design learning contexts for students to experience SDL processes as SDL entails uncertainties that pose challenges to both teachers and students (Bolhuis, 2003). This study will explore what aspects of learning contexts could lead students to face uncertainties and how students overcome these uncertainties to construct knowledge in the SDL process. The exploration will give practical implications for teachers to design learning opportunities for students to experience SDL in class.

This study explores the process of student learning in a self-directed STEM class for 4^{th} graders in a school which has been collaborating with our university research team for nearly two years by the time of the class. The university team adopts the practice of design-based implementation research (DBIR) (Fishman, et al., 2013) and engages in *infrastructuring* which provides design principles for forming innovative practice (Penuel, 2019). The DBIR project supports teachers in creating school-based STEM lessons with an emphasis on SDL.

The university research team informed teachers of the guiding principles for creating self-directed STEM learning opportunities for students but did not offer any prescriptive curriculum for teachers. One overarching guiding principle is about knowledge integration in STEM (CDC, 2015). The integration emphasizes the importance of linking knowledge and practices of different STEM disciplines for problem solving (Bryan, et al., 2015; Johnson, 2013; Kelley & Knowles, 2016).

Another overarching guiding principle is self-directed learning (SDL). The project distinguishes SDL from self-learning. Five main components of SDL are identified to form an operational framework to guide teachers to design self-directed STEM lessons. The five components are goal-setting, self-planning, self-monitoring, self-evaluation and revision (Hew, et al., 2016). The operational framework acknowledges that learners actively diagnose their own learning needs for setting their own learning goals and planning their learning journey with the decision on learning resources and strategies (Knowles, 1975).

To visualize how students learn with the SDL process, this study adopts a qualitative case study approach informed by the scholarship of interactional ethnography (Green and Bridges, 2018). A close examination of interactions in a focused lesson was taken, accompanied by tracing the relationship between separated events in the focused class as well as its relationship to the wider contexts were investigated. The following research questions guide our case study.

1. Compared with traditional didactic classroom, how do uncertainties arise for students in the lesson designed by SDL approach?

2. How do students overcome uncertainties and construct new understandings in the STEM lesson through the SDL process?

This paper begins with a literature review on SDL, followed by explaining the logic of interactional ethnography which guides the case study. A thick case description is presented in the findings. The learning process of a group of 4th graders will be visualized. Then the dynamic between aspects of learning contexts and the autonomous processes in SDL (Hew, et al., 2016) will be revealed. Student agency is addressed through this dynamic. The findings give implication to the design of SDL lessons for young students.

Conceptual framework

Self-directed learning

Self-directed learning (SDL) embodies both processes of learning and the development of self-direction as learners' personality characteristics (Brockett and Hiemstra, 2018). The building of self-direction is crucial to life-long learning as with self-direction learners are capable of taking ownership and responsibility of what and how they should learn. Traditionally teachers take the role of disseminating knowledge in classroom for students to acquire and act according to what teachers tell them. Such traditional classroom is unable to foster self-direction among students (Hiemstra, 1994). To develop learners' self-direction, it is important that teachers are able to design opportunities for students to undergo the SDL process in classroom settings (Tan, et al., 2011). This is to nurture learners' personal attributes with self-direction at an earlier age for their life-long learning.

The SDL process is not equal to self-learning. According to Knowles (1975, p. 18), SDL is "a process in which the individual takes the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes". The SDL process can take place with the help of teachers and peers. It emphasizes how learners can understand and achieve their goals, entailing self-regulation in which learners evaluate and make adjustment. Zimmerman and Campillo (2003) propose three phases of learning with self-regulation. The forethought phase involves goal setting and planning. The performance phase is about self-monitoring where cognitive and metacognitive functions with self-control and self-observation are at work. Then learners enter the self-reflection phase to judge and revise their learning goals or strategies. There are autonomous processes when students take on SDL.

Various scholars have delineated what the SDL process involves and Hew, et al. (2016) put forward an SDL model (figure 1) with five main autonomous processes of SDL: goal setting, self-planning, self-monitoring, self-evaluation and revision. These five autonomous processes resonate with Knowles' (1975) definition of SDL process and key processes in the three learning phases for learning with regulation proposed by Zimmerman and Campillo (2003). In Hew, et al. (2016) model, the five autonomous processes of SDL are in relation to learning contexts and personal attributes. This study will contribute to enriching our understanding of the dynamic between the autonomous processes of SDL and learning contexts. This dynamic relationship will give us hint on the design of learning for SDL.

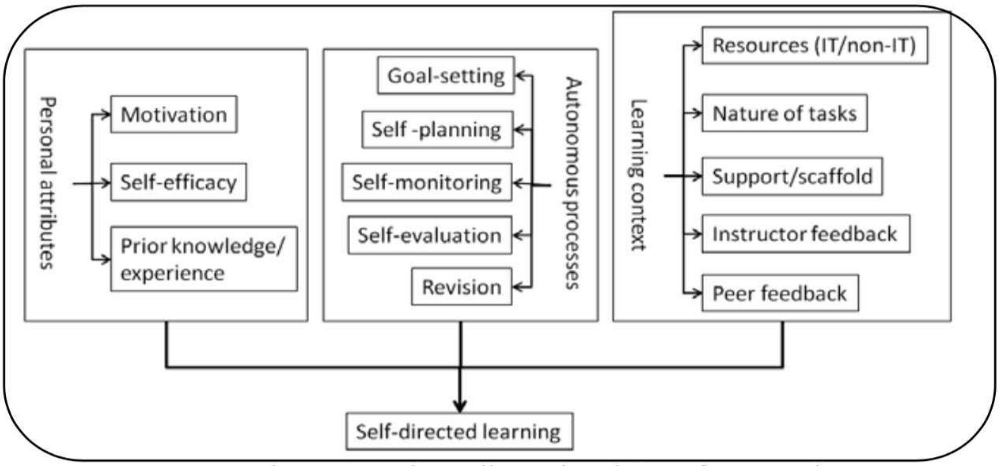

Figure 1. A three-dimensional SDL framework (Hew, et al., 2016, p.680).

Self-directed learning with process-oriented pedagogy

The SDL process can be used to orient pedagogy (Bolhuis, 2003; Tan, et al., 2011). For example, the five autonomous processes of SDL could enhance the practice-focused learning in integrated STEM education. Students experience part of the practices as scientists or engineers like setting goals for their works when they ask inquiry questions or identifying problems. They plan and monitor their investigation or design process of experiments and tests. They evaluate and revise their goals, methods or prototypes until they achieve optimal outcomes. The components of the SDL process provide guidance for teachers to design STEM lessons for students to experience STEM practices and in turn cultivate their self-direction. This study argues that how students undergo the autonomous processes of SDL are shaped by and shapes learning contexts. It is why SDL as a process-oriented pedagogy would bring uncertainties in classroom (Bolhuis, 2003). This study will research on how greater uncertainty can be generated in an SDL class when compared with traditional didactic classroom. It will answer the question of how to harness generated uncertainties into learning. To achieve better understanding, this study will examine how students learn and construct knowledge in a STEM class with SDL process-oriented pedagogy.

Method and research context

Research design

This study adopted the logic of inquiry in interactional ethnography (IE) (Bridges, et al., 2012; Bridges, et al., 2015; Green and Bridges, 2018) to systematically examine how students constructed knowledge in a STEM class in which they were given opportunities for self-directed learning (SDL). The logic of IE offers us an analytical framework to address the interconnected elements over time and across contexts. It guided us to zoom in on the interactions when students underwent the SDL process and zoom out to examine the consequence of those interactions to the system. The examination makes visible the situated understandings of science practice of fair test in a STEM class for 4th graders and how uncertainties are generated and overcome in the process. The boundaries of a telling case study in a classroom system are constructed by a sequence of events, with which theoretical inferences are made with thick description of the configuration of events, involved actors at particular moments and situations (Spradley, 1980). An event map (figures 2 and 3) was constructed for telling case (Mitchell, 1984) for the STEM class. The event map constitutes key processes, showing the ebb and flow of activities across a period of time in a class session (Spradley, 1980).

The telling case in this study focused on a class of students (n=27) engaging in the task of testing the performance of their hand-made anemometers in a STEM lesson. One member of the class, G1, was selected as an anchor point because the successful creation of a stable testing set-up by G1 and her three groupmates (G2, B1, B2) provided a rich point (Agar, 1994). This rich point guided us to systematically map forward and backward to see the learning journey of G1 in some sequence of events in the class to trace how G1 and her classmates encountered and overcame uncertainties to create their solution. The mapping process unfolded the development of their learning in STEM practice by looking into how learning in one context was consequential to learning in other contexts (figure 3). The mapping process was informed by the analytical constructs of IE (Bridges, et al., 2012; Bridges, et al., 2015), involving the iteratively tracing process for finding the interconnections between texts such as talks, written words and visual aids across events in different contexts from the rich point (Agar, 1994). The interconnections and interdependency of texts and of contexts corresponds to the emphasis of *intertextuality* and *intercontextuality* in IE (Bridges, et al., 2015). The re-presentation of the sequence of events with timelines in an event map provides ethnographic space for mapping interconnected events in different settings (e.g. whole class discussion, group activity) and identifying "the intertextual chain of events" (Green and Bridges, 2018, p.481).

The inquiry process involved the finding of "whole-part, part-whole relationship" (Bridges, et al., 2015, p. 117). The examination of events thus entailed the focusing into individuals and focusing out the learning contexts for tracing the connection. This is to trace the relationship between what individual students talked and acted and what had been going on in the learning environment. The search of such relationship would show how the connection between the learning contexts and the autonomous processes of SDL.

Context of the study

The study took place in a STEM class for 4th graders in a primary school in Hong Kong. The school had been in partnership with a university in Hong Kong for almost two years by the time of the class. The partnership began with a project about promoting SDL in science and moved on to another project about promoting SDL in STEM. The STEM lesson was designed by an interdisciplinary teacher team in the school with consultations offered by the university team including the author and teachers in the project network during the design process. The STEM topic was "Anemometer". Students were challenged to make an anemometer and tested its performance with the science practice of conducting a fair test. The focused lesson in this study was the last session of the STEM topic.

Data collection and analysis

The structure of the ethnographic archive for the focused lesson was organized in table 1, providing relevant contextual information about the sequence of events in which the anchor student G1 involved. Methods of data collection include video-recording of the focused lesson at different angles, photos of various moments in the focused lesson, learning artifacts generated by students, student work on their worksheets and on a Moodle-based e-learning platform. The contextual understanding of the event also supported by data from audio-recordings of co-planning session before the focused lesson, teacher debriefing and student focus group interview after the focused lesson. Conversations in the focused lesson were transcribed and checked by university research team members. Students spoke Cantonese, but occasionally with few English terms. The conversation analysis was done with original utterances. These utterances were translated to English in this paper. The translation follows the sequence of original utterances. The translated utterances are presented with the convention adopted from Bridges, et al. 2015 (p. 130).

Based on the contextual information provided by the data, the historical timeline for the telling case from the pre-class task to the end of the class was laid out in the form of an event map (figures 2 and 3). In each event, conversations in the whole class discussion and in the group with G1 were analyzed. The event map constitutes key processes related to the task, showing the ebb and flow of task-related activities across a period of time (Spradley, 1980). The relationship between the focused lesson and its larger context is visualized in the event map. The lesson was the last part of the learning topic, Anemometer (figure 2). Before the lesson, students had already made and revised their hand-made anemometer. During the lesson, students needed to evaluate the sensitivity of their anemometer by testing how the anemometer responded to different wind strength. The making of a stable set-up in G1's group provided a rich point for mapping backwards and forwards to see how G1 and her groupmates develop their understandings for the set-up across time and between conversations. The mapping traced how learning across events and between conversations would be consequential to each other (figure 3). This involved the investigation of how SDL was facilitated in the classroom and how students were enabled to construct their understandings of variables in the fair test through SDL. The investigation revealed the uncertainties that students encountered and overcame in the SDL process.

<u>Table 1: Ethnographic archive for the focused lesson</u>

Events in the classroom	Data source	Length of the segmented video clips captured by the main camera	Length of the two video clips captured by second video camera, in the back of the classroom	Length of related segmented video clip capturing G and her groupmates by mobile devices
First whole class discussion	Videos	V1 (00:10:06)	V9 (00:37:19)	
First group activity	Videos, photos, artifacts, records on the e-learning platform	V2 (00:12:36) V3 (00:00:28)		M1 (00:00:16) M2 (00:01:40) M3 (00:00:07) M4 (00:00:23) M5 (00:00:24) M6 (00:00:18) M7 (00:00:10)
Second whole class discussion	Videos	V4 (00:16:36)	V10 (00:31:46)	
Second group activity	Videos, photos, artifacts, records on the e-learning platform	V5 (00:03:47) V6 (00:04:08) V7 (00:00:29)		M8 (00:00:15) M9 (00:00:20) M10 (00:00:45) M11 (00:00:19)

Final whole class discussion	Videos	V8 (00:13:10)		

Grade 4 STEM topic	Anemometer (Spring 2018)							
Subject	**Mathematics (Math)**		**General Studies (GS)-related to Science learning for this topic**					
Lesson[1]	1st Math lesson	2nd Math lesson	1st GS lesson	2nd GS lesson	3rd GS lesson	4th GS lesson	5th GS lesson	6th GS lesson
Learning area or learning activity	Average calculation	Units for wind speed	Wind direction, and the relation between wind speed and wind power	Measurement about wind, different types of anemometer and DIY anemometer	Individual plan for a high sensitive anemometer	Design an anemometer (group work)	DIY anemometer (group work)	Testing the anemometer

Testing the anemometer				
Event 1: First whole class discussion	Event 2: First Group activity	Event 3: Second whole class discussion	Event 4: Second Group activity	Event 5: Final whole class discussion
10:05-10:15	10:15-10:30	10:30-10:46	10:46-11:00	11:00-11:13
Goal setting	Initial planning and monitoring in group			
		Evaluation and Revision		

Figure 2. Event map illustrating how the focused lesson relates to its larger context.

Testing the anemometer				
Event 1: First whole class discussion	Event 2: First Group activity	Event 3: Second whole class discussion	Event 4: Second Group activity	Event 5: Final whole class discussion
10:05-10:15	10:15-10:30	10:30-10:46	10:46-11:00	11:00-11:13
Goal setting	Initial planning and monitoring in group			
		Evaluation and Revision		
… (10:07:59) S1: Seeing it turns or not (10:08:00) T: Right (.) Whether it can turn… If it can't turn(.) can the windspeed be tested? ((Some students are shaking their heads including G1)) …	… (10:17:04) G1: 30 seconds (.) Then see if under the weakest wind it (the anemometer) can move or not (.) … (10:22:31) G1: Strong wind is difficult to see (10:22:32) U3: Try putting it a bit farther. Will it be easier or not (10:22:54) G2: It stopped ((The anemometer stopped moving. G1 slightly moved her fan closer to the anemometer and the anemometer turned again)) …	… (10:39:47) T: Why the whole testing should address reliability? It is because want to achieve a fair test. Then how to be fair? (10:39:57) T: What does it mean all things are the same? What should be the same? … (10:40:17) G1: Fan's distance (10:40:19) T: Yes the distance the fan is put	… (10:46:44) B2: 21cm can be used or not with the weakest wind (10:46:46) G1: can move (10:46:47) B2: What. 21cm is like this ((B2 used his hand to make longer the distance)) … (10:47:28) G1: =Use (.) We use the weakest wind first. But we are like this as far as one ipad distance. This is the weakest wind. ((B2 was holding the electric fan at one ipad distance but the anemometer did not move)) (10:47:41) G1: Your angle is problematic. You have to point it at a correct angle. If you point at an incorrect angle, you cannot make it. (10:48:02) G1: = face to face ((moving the fan which was still holding by B1 until the blades moved)) Yes you can make it turn … (10:55:00) G1 and her groupmates created a stable testing set up	… (11:02:37) G1: That is put err… water bottle here ((G1 moves her hand to mimic the situation as the set-up has been dismantled)) Then put the fan on its top and face at a right position to the anemometer. Then can get the right position to face at. Facing at an incorrect position cannot make it turn.

Figure 3. Event map illustrating the mapping process in the data analysis.

Findings and discussion

This section first discusses what uncertainties are identified in the process of student learning in the focused lesson and elaborates on how students made these uncertainties into certainties. Then, the findings are summarized to answer the two research questions.

An objective of the focused lesson was about building the practice of fair test among 4th graders. Unlike the traditional cookbook experiment, students were given no standard step-by-step procedure to follow. The learning contexts, including nature of tasks, resources and scaffolds were designed to facilitate the five autonomous processes of SDL: goal-setting, self-planning, self-monitoring, self-evaluation and revision (Hew, et al., 2016).

In event 1, students shared various levels of goals for their anemometer. The basic goal was that the turbine of the anemometer would turn. The highest goal was that the anemometer would be sensitive to different wind strength. Then they were challenged to find a method to test the sensitivity of their anemometer. It is found that the nature of task design and the diversity of resources in this lesson gave rise to uncertainty. Teachers designed the task as an open-end inquiry with no standard solution, particularly, when each group of students had created their unique anemometer as a resource for their learning. Students and the teacher were uncertain about the solution for individual groups.

In event 2, students planned and monitored their tests for the anemometer. Teachers designed a worksheet with space for students to write their plan and data. Students were hinted to set their time and record the number of rotations of their anemometer upon blowing with different strength of winds generated by a handheld electric fan. The designed scaffold in the learning contexts (Hew, et al., 2016) only gave guides for students to monitor their work but students needed to make decisions and record for the variables entailed in the test. It is found that students encounter uncertainties in their decision making. One of the biggest uncertainties discussed by G1 with her groupmates was the control variable of distance. G1 and her groupmates needed to decide on the distance between the electric fan and their anemometer for the test. They set criteria that the right distance should let the anemometer turns under the weakest wind while the number of turns was still be able to be counted in-the-moment under the strongest wind. In the class, more and more groups started using mobile technology to record the test and count the number of rotations by slow motion function. Peer group observation was allowed in the setting. It is found that the diversity among groups facilitated peer-learning and self-regulation. Then G1 and her groupmates also started to use mobile technology to help with counting. The method for measuring the dependent variable of number of rotations was regulated. Consequently, they could decide on the distance for the test. Yet, by the end of the first group activity, G1 and her groupmates did not achieve any good set-up for their test.

In event 3, the teacher scaffolded students' self-evaluation by talks based on students' testing experience in event 2. The teacher faced uncertainties in the discussion, as every group was different in their progress and carried different testing experience. The teacher raised a reflective question of how to achieve reliable fair test for students to evaluate and self-regulate (Zimmerman and Campillo, 2003). Reliable fair test was the assessment criterium for self-evaluation. The diverse and unpredictable experience among students in the first group activity was used to scaffold student further learning via this regulative feedback question (Hattie and Timperley, 2007). G1 contributed her idea by articulating the importance of keeping distance the same. This connects to the decision of farther or closer in the first group activity though their group did not measure the distance by that time. The knowing of distance as a "thing (variable)" to be controlled (CV) is based on their hands-on experience instead of just being told. Mapping backwards, though the term "controlled variable" or even "variable" was absent throughout the lesson, the goal of making a reliable testing set-up drove the development of the understanding of variables. Students were given epistemic agency to contribute what should be controlled based on their prior experience of imperfect testing, which was with unfairness and mistakes. It is found that the diverse results and articulations from students shaped the learning contexts of scaffolds and feedback when overcoming uncertainties.

In event 4, G1 and her groupmates (B1, B2, G2) overcame the uncertainty of distance and made it certain by using the criterium of their anemometer's ability to move under the weakest wind produced by an electric fan. They started to describe the variable of distance in different ways. Instead of just saying "closer" or "farther away", they measured the distance and at times uttered "21 cm" with the unit (table 2). They also re-presented "the same distance" as "one-ipad" (table 2, 10:46:49) when they were controlling this variable.

Table 2: Excerpts from event 4: Second group activity (Transcripts from V5, 00:00:14-00:00:55)

Relative time	Conversation
10:46:38	B2: See 21(.) 21cm whether it can work under the weakest wind ((G1 takes away the fan from B1 and turns on the fan))
10:46:44	B2: If 21cm cannot be used with the weakest wind, would it be useful?
10:46:46	G1: Can move ((The anemometer is moving))
10:46:47	B2: What. 21cm is like this ((B2 uses his hand to make longer the distance))
10:46:49	G2: OK you measure ((G2 is taking the ipad but G1 then is taking it away. G1 use the ipad to measure the distance of 21 cm. The anemometer keeps moving))

Event 4 provided time for them to continuously evaluate and revise their set-up. Their handmade anemometer maintained a resource for their learning. Learning is affected by the socio-materialistic interaction in a context (Hutchins, 1995). It is found that the socio-materialistic interaction in the group generated another uncertain variable to be monitor. B1 noticed the anemometer stopped turning even at the controlled distance and put forward a doubt, “I feel it stopped” (table 3, 10:47:11). G1 then asserted her viewpoint, “Your angle is problematic” (table 3, 10:47:28). The discourse of “angle” emerged within the group and was subsequently embodied in the phase of “face-to-face” (table 3, 10:47:56). Keeping “face-to-face” related to the monitoring of another variable of height. G1 and her groupmates realized the difficulties of using human hands to maintain a stable position for keeping “face-to-face”. Consequentially, they used materials that they had at hands to make a temporary stable set-up for the testing. It is found that the SDL process shapes the learning contexts again by changing resources for learning.

Mapping forwards to event 5, G1 contributed to the class by sharing the idea of “face at a right position” and the teacher used her sharing to add the idea of “angle” as a controlled variable in the test. Again, student agency is valued. The in-the-moment learning outcomes from the SDL process shapes learning contexts of scaffolding new concept in the class.

Table 3: Excerpts from event 4: Second group activity (Transcripts from V5, 00:01:28-00:02:07)

Relative time	Conversation
10:47:11	B1: No:: it stops:: I feel it stopped↑:: Number-one-wind or Number-three-wind?
10:47:28	G1: =Use (.) We use the weakest wind first. But we are like this...((looking at how B1 was holding the electric fan and then making the fan farther away from the anemometer)) farther as far as one ipad distance. This is the weakest wind? ((B1 was holding the electric fan at one ipad distance but the anemometer did not move)) **Your angle is problematic**. You have to point it at a correct angle. If you point with an incorrect angle, you cannot make it. That is you try this angle ((putting the fan beside the anemometer and then the anemometer moves)). Blowing at this side like this can work! ((looking at B1 amazingly and then turning to G2)) G2 (.) Blowing on this side is workable!
10:47:55	G2: Then which angle do you want to use?
10:47:56	G1: = face to face face to face face to face face to face (.) face to face ((moving the fan which was still holding by B1 until the blades moved)) Yes you can make it turn
10:47:07	B2: it is turning now.

In response to the first research question, it is found that compared with traditional didactic classroom, uncertainties students face in the lesson designed by SDL approach are caused by various aspects of learning contexts as in Hew, et al. (2016) model. First, the nature of the task is open-ended and accommodates diverse results. Second, the scaffolds only guide and inform what decisions and records students should make. Students are reminded to make more decisions, which imply uncertainties. Third, the feedback students collected via socio-materialistic interaction (Hutchins, 1995) may cause doubts on their decisions. In response to the second research question, it is found that students are enabled to overcome uncertainties and construct new understandings in the STEM lesson with the SDL process because of the following conditions. First, uncertainties could produce diverse results which could be harnessed for supporting peer-learning. Second, the autonomous processes of self-evaluation and revision could be directed by uncertainties with the support of regulative feedback **(**Hattie and Timperley, 2007**)**. Third, students were able to exercise their agencies to contribute even if they were based on their failure experience. The self-organization of students in the SDL process in turns shapes the learning contexts such as generating new scaffolds and regulative feedback.

Conclusions and implications

SDL process-oriented pedagogy is challenging to both teachers and students because of the uncertainties it entails (Bolhuis, 2003). This study uses the scholarship of interactional ethnography (Green and Bridges, 2018) to explore uncertainties that the anchor student G1 encountered in an SDL oriented STEM lessons. This study showed how she together with her groupmates overcame those uncertainties. It finds that uncertainties are necessary in designing learning for students to experience the SDL process. Uncertainties drive students in the quest for solutions. The design of the learning contexts, such as learning tasks, scaffold, feedback, shapes how students undergo the SDL process. At the same time, the in-the-moment consequential outcomes of SDL process could reciprocally shape the scaffold and regulative feedback (Hattie and Timperley, 2007) in the learning contexts. This study contributes to illustrate the existence of dynamic between the autonomous processes of SDL and the learning contexts in the SDL model (Hew, et al., 2016).

The findings imply that the pedagogical use of the in-the-moment consequential outcomes of the SDL process is critical to facilitating student agency and subsequent autonomous processes of self-evaluation and revision. In doing so, students find certainties from uncertainties. By valuing student agency in the SDL process, students are facilitated to grow self-efficacy in their personal attributes (Bandura, 1977; Hew, et al., 2016). Teachers also face uncertainties in the process, particularly, when the unpredictable in-the-moment consequential outcomes from the SDL process could shape learning contexts. Further research can be done to search for principles or patterns for informing teachers how to harness the unpredictable in-the-moment consequential outcomes to facilitate students to face uncertainties via the SDL process.

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