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To See Reason: Technology Teachers' Guidance and Students' Reasoning in the Design Process

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ABSTRACT

In this study, the aim has been to explore teacher guidance in relation to students' reasoning in the design process. It is important that technology education develops students' reasoning in design so that the students can learn to draw conscious conclusions and to make the thought process behind these conclusions explicit. The teacher's support is pivotal to this learning. However, research on teacher guidance when students reason within technology education is limited. Nonetheless, gaining knowledge about this would support further insights in how to develop students' reasoning in design. Data has been collected through two classroom observations of lessons in technology education in Swedish secondary schools. Video and audio were recorded using two cameras and teacher-mounted and student group microphones. Transcribed video and audio data were analyzed through thematic analysis. In the results, the teacher interventions have been described and presented in relation to the important reasoning types in design; means-end reasoning and cause-effect reasoning. Findings indicate that the students' reasoning is more explicit through verbal expression when the teacher asks counter questions or questions to check-up or to challenge the student's actions. The results of this study will be beneficial to propel further research about teaching in relation to students' reasoning in design.

Key Words: Technology Education, Design process, Reasoning, Teacher interventions, Teacher-student interaction

1. INTRODUCTION

Students practicing and learning to reason about technology, would ideally be an ingredient in technology education. Ankiewicz et al. (2001, pp. 190) states that "depending on how technology education is taught, it can either promote the desired thinking skills or be reduced to the craft subject from which it originated". Hence, what technology teachers do in the classrooms and how they arrange learning situations is central to how students develop their reasoning. At the same time, reasoning is a broad concept. However, it is commonly acknowledged as the thought process of posing premises leading to a conclusion (e.g. Harman, 1986). Following this broad view, we can derive that the ability to reason is an integral aspect of technological literacy, as it encompasses maintaining, controlling, and operating in order to draw conclusions and make decisions in relation to technology (Alamäki, 2000; Rossouw et al., 2011). Consequently, recognizing the strong correlation between reasoning and decision making, Kruse (2013) emphasized the significance of incorporating reasoning development into students' technology education.

Moreover, technology education is a vast subject. Yet, at its core is the design process, with regards to content of curricula around the world (Norström, 2016). The design process is usually described as the steps or actions taken to reach a goal by designing (Wikberg-Nilsson et al., 2021). Considering the reasoning in this process is essential and Cramer-Petersen et al. (2019) emphasize that making sense of the reasoning in the process is necessary for comprehending the design practice. Therefore, for the teacher to be able to guide students in their learning in the process, considering the reasoning in the process can be fruitful (Seery et al., 2022). Hence, unpacking the students' reasoning in the design process can support the teachers in guiding their students in the process.

1.1. Aim and Research Question

Considering the students' reasoning in the design process can be deemed important. The teacher and their guidance are at the center of this. However, within technology education research, teacher guidance in relation to students' reasoning has not been investigated to any great extent. Nevertheless, gaining knowledge about this would support further insights in how to develop students' reasoning and learning in the design process. Consequently, the aim of this study has been to contribute to this research by posing the following research question.

1.1.1. Research question

What teacher guidance emerge in teacher-student interactions in relation to students' reasoning in the design process?

2. LITERATURE REVIEW

Within the literature, the teacher's role within the design process is usually described as of a guiding nature (e.g., Goldschmidt et al., 2014; Kimbell & Stables, 2007). In a recent study by Sheoratan et al. (2023), different types of feedback and questions used by teachers to support students in a design process were identified. The inductively identified feedback that was used by the teachers were steering feedback, encouraging feedback, and clarifying feedback. The questions that the teachers used was deductively identified as low-level questions, deep reasoning questions, and generative design questions, using a classification of questions described by Eris (2004).

Extensive research has delved into the reasoning logic employed by designers (e.g., Cramer-Petersen et al., 2019). However, there is limited amount of research on reasoning within the design process in the field of technology education and as reasoning is such a broad concept, the research made within the context of technology education is scattered. Daugherty and Mentzer (2008) found that expert designers frequently utilize analogies, suggesting the need for further investigation into the implications of analogical reasoning in technology education. Similarly, Buckley et al. (2018) have highlighted the significance of inductive reasoning and advocated for its integration into technology education. Thorsteinsson and Olafsson (2016) as well as Autio and Soobik (2017) have examined students' reasoning in technology education with a general approach. There has however not been a focus within these studies on reasoning explicitly connected to the design process in technology education.

3. METHOD

3.1. Data Collection

To be able to interpret and analyze teacher guidance in connection to student’s reasoning, data was collected through observations of lessons in Swedish Secondary School. In total, a set of two different observations of technology lessons were made. The intention was to receive a rich data material containing descriptions from technology teachers and their practice. Consequently, teachers that had experience as technology teachers and that had had the time to develop their practice were selected. To establish such a selection, a subjective selection in combination with a snowball selection was made (Denscombe, 2018). One of the teachers, from now on called Bob, taught a nineth grade class and they were working with developing a ventilation system for a location of the student’s own choice. During the observed lesson, the students had made drawings and were in the process of making physical models. Here, 17 students participated in the observation. The other teacher, from now on called Peter, taught a nineth grade class who were in the middle of drawing their dream house. 14 students participated in this observation. All participants had been provided with information about the study prior to the data collection, and they had all signed a written consent form. Additionally, for the students that were under 15 years old, their legal guardians consented in writing as well. The students that did not want to participate in the observations attended the lessons in adjacent rooms.

As the researcher, I participated in the observations as a complete observer. This meant that I participated in the classroom during the lesson without interacting with the teacher or students (Baker, 2006), except to interact to inform or answer questions about the observation or the research study. Data of the situation and interactions was collected through audio recordings of the teacher through a microphone mounted on the teacher. To fully capture the whole interaction, I also made audio recordings of the students through microphones being placed close to each group of students. In addition to this, data was also recorded through video recordings of the classroom. This was made through two cameras filming from two angels in the classroom. The use of two cameras made it possible to capture gestures, movements and artefacts that are important for the context of the interactions. But it also made it possible to arrange the cameras to avoid filming parts of the classroom and avoid filming students that did not want to participate in the study. The two cameras also provided a backup if the equipment were to malfunction. This turned out to be a necessary backup as one of the cameras stopped filming due to overheating.

3.2. Data Analysis

The audio and video data from the observations were jointly transcribed and the interactions between students and the teacher was divided into teacher interventions (cf. Mortimer & Scott, 2003). A teacher intervention was defined as the moment when teacher and student started to interact, and it ended when one of them left the interaction. Teacher interventions that were deemed to not be relevant to the research question or where the context was difficult to comprehend, were removed from the data set. A total of 29 teacher interventions were then analysed through thematic analysis as described by Braun and Clarke (2006).

In the data, both the teacher's actions and verbal expressions in addition to the students' reasoning was of high interest. Thus, the data was coded both deductively with regards to the students' reasoning, and inductively with regards to the teacher's actions and expressions. A model for reasoning in the design process in technology education described by Hultmark (2022) was used as a theoretical framework for the students' reasoning. The model describes the two reasoning types means-end reasoning and cause-effect reasoning and their relationship within in the design process. Through means-end reasoning the students draw conclusions about means that will realise the desired end. Moreover, they base these conclusions on beliefs about cause and effect relationships that can be formed through cause-effect reasoning. To answer the research question, themes were formed considering both the deductive and inductive coding.

4. RESULTS

When the teacher interventions were analysed, three themes were identified. When interacting with the students the teacher was *giving answers, asking questions,* and *showing their reasoning* and the verbal expression of the students' reasoning varied with these interventions.

4.1. Giving Answers

The analysis resulted in three subthemes when the teacher was giving answers to their students' questions: *Counter question*, *vague answer* or through *providing a conclusion*. There is a distinct difference in the explicitness of the student's reasoning connected to the teacher's answers. When the teacher answered or reacted through counter questions, the students' reasoning was verbally expressed. The students' reasoning is then foremost expressed through them stating conclusions in the form of stated actions or beliefs. One example of this is when the student Alex askes the teacher Peter a question (Excerpt A). Alex wonders whether it is actually good with many windows in a house (A1). Instead of answering the question directly, Peter askes a counter question (A4). When answering this counter question, Alex's cause-effect reasoning is expressed when he formulates a belief about the effect of many windows (A5). He also provides the premise that it is because they take up space on the wall. Peter confirms Alex's conclusion, but following Alex's reasoning, he asks a question that broadens the perspective (A6).

Excerpt A.
Counter question

A1.	Alex:	Peter, I have a question for you. Is it actually good with many windows in a house?
A2.	Peter:	Many windows?
A3.	Alex:	Yes
A4.	Peter:	Why would it be bad?
A5.	Alex:	Doesn't it lower the [insulation effect]? You know, they take up space on the wall.

A6.	Peter	Yes, so the insulation effect does definitely get worse. But what do you get with many windows? [Pause] Light!

The teachers could also answer students' question by not giving a direct answer. Instead, the teacher gave a vague answer, where these answers were characterized by the notion of prompting students to decide and reach a conclusion on their own. In Excerpt B, this is prominent when the teacher Bob explicitly says that the student, Maria, should reach a conclusion on their own (B2). In contrast to this, the teacher sometimes answered by providing conclusions. The teacher Peter provides conclusions in Excerpt C (C2, C4), when the student Isabel asks if they should add stairs and draw a ramp or not.

Excerpt B.
Vague answer

B1.	Maria:	Should there be a piece of wood under this one too?
B2.	Bob:	You decide. You are the project manager. Nobody should tell you what to do. What your design looks like is up to you.
B3.	Maria:	Mhm

Excerpt C.
Providing conclusion

C1.	Isabel:	But then I would add stairs?
C2.	Peter:	Yes, it's just one step. If you have 0.3.
C3.	Isabel:	Yes, but if I then had a ramp. Or would I […] Would I build it down?
C4.	Peter:	For the garage, then it's better to bring the garage down to ground level and then you have no foundation.
C5.	Isabel:	So I do this directly? [Points to the drawing]
C6.	Peter	Yes

In the interventions where the teacher provides vague answers or when they provide conclusion, the student's reasoning is not explicitly expressed. In the cases of when the teacher provides vague answers, the students reasoning can be expressed in a later stage depending on the conclusion they reach in the form of actions. When the teacher provides conclusion, the students instead express confirmation or asks follow-up questions.

4.2. Asking Questions

Among the questions that the teacher asked the student in the interventions, the analysis yielded in three different subthemes: questions to *check-up*, to *challenge* student's conclusion or to *confirm* that the student understands what the teacher means in a particular case. In Excerpt D, the teacher Bob can be seen to check-up on the student Kim by asking how it went (D1). Kim's answer shows a conclusion in a cause-effect reasoning (D4). In Excerpt E, the teacher Bob can instead be seen to challenge the student Nina's action to use a small wood piece by questioning her action (E3).

Excerpt D.
Check-up

D1.	Bob:	How did it go for you, Kim? Did it go well? Or so-so?
D2.	Kim:	Yes, I am trying to fix this piece
D3.	Bob:	Okay
D4.	Kim:	But the glue didn't work very well

Excerpt E.
Challenge

E1.	Bob:	Wood piece underneath? [Shows with a wood piece]
E2.	Nina:	It is here [points to the wood piece]
E3.	Bob:	Why do you use that small wood piece?
E4.	Nina:	Because it doesn't need to be lifted up, so it doesn't go up like that. [Shows steep slope with model]. It is quite close.

Both when the teacher asks check-up questions and when they ask challenging questions, the student's reasoning is visible through verbal expression. The student Nina's (Excerpt E) means-end reasoning behind her conclusion is made explicit (E4) through the challenging question asked by the teacher. When the teachers ask questions to confirm, the students' answers are short and affirmative.

4.3. Showing their Reasoning

In the teacher interventions, apart from giving answers and asking questions, the teachers also made interventions where they themselves were showing their own reasoning. This was the case when they were providing support or making corrections without a request by the student. In Excerpt F, the teacher Bob has noticed a need to raise a part of the model a bit more and suggest an action (F1). The student Kim questions the conclusion by means of a question (F2), and the teacher's reasoning becomes explicit when providing premises (F3). This is also evident when, in Excerpt G, the teacher Peter provides support by making parts of his reasoning explicit to the student Nour (G2) who are in the process of writing about her reasoning behind her decisions.

Excerpt F.
Making corrections

F1.	Bob:	How many should you have? You must put two
F2.	Kim:	Two?
F3.	Bob:	Yes, we raise it a bit more
F4.	Kim:	Yes okay, yes but I will do it

Excerpt G.
Providing support

G1.	Nour:	Is it good? Should I write about my choice of windows and stuff too?

G2.	Peter:	Yes, you can do that. The most important thing is the walls. But there are windows on the walls, and since windows are the most poorly insulated part of a wall, you can write about the windows and the impact of choosing energy-efficient windows or not.
G3.	Nour:	Should I link the pages at the bottom?

Within this theme, that the teachers providing support through showing their reasoning or parts of their reasoning is prominent. When this is explicit the students either confirms that they follow the teacher's reasoning and act accordingly or they ask question for the teacher to elaborate more.

5. DISCUSSION

The findings of this study shows that the teacher guided their students through *giving answers*, *asking questions*, and *showing their reasoning*. Within each theme the action or verbal expression of students differed in connection to the teacher's guidance. The results emphasize how teachers withholding direct answers from students through counter questions occurs in connection to the student's reasoning being more explicit through verbal expression. The same occurs when the teacher asks questions to check-up on student work or when challenging an action made by the student. The results also showed that both the students' means-end and cause-effect reasoning were made verbally explicit in connection to the teacher guidance.

These results have implications for technology education. By prompting students to articulate their reasoning, teachers can act upon the content of the reasoning and decide on appropriate support. This is in line with what Cramer-Petersen et al. (2019) emphasizes, that making the reasoning explicit supports understanding of design practice. This is also consistent with the discussion of Seery et al. (2022, pp. 12) and that using the frame of reasoning is useful "to unpack the myriad of observed activity". This implies that framing the students' actions and statements through the frame of reasoning is useful to delve into the intricate nature of the design process, which can serve as a foundation for the teachers to support their students in their design endeavours and learning.

In this study, the focus has been on teacher guidance in isolated teacher-student interactions and to relate this to the students' reasoning. To gain more knowledge about this interplay, further studies covering the whole design process or reoccurring guidance of students is desirable. However, the results of this study provide valuable insights to advance further research on teaching concerning students' reasoning in the design process.

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