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Involving students in sharing and clarifying learning intentions related to 21st century skills in primary design and technology education

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Abstract

Design and Technology Education is an excellent vehicle for the development of the so-called 21st-Century skills, such as creativity, critical thinking and cooperation. However, the development of these skills through design projects does not yet reach its full potential. Formative assessment is able to support the learning of 21st-Century skills. In a case study a teacher shares and clarifies the goal of divergent thinking with her class of 11- and 12-year old's using a newly developed interactive approach. Small drawings were made collectively to visualize the skill. Half-way during the brainstorm session, students were asked to assess their brainstorm results and divergent thinking skills in a collective reflection. The results show that the interactive visual approach led students to understand how to be successful in divergent thinking. They collectively developed expressions to talk about how sound divergent thinking looks and this enabled them to diagnose strengths and weaknesses in divergent thinking. All interviewed students reported an improvement in divergent thinking after the collective reflection. This indicates that active involvement of students in clarifying learning intentions enables the development of relevant feedback. Although this result was only achieved in one class with one particular teacher, it underlines the value of the interactive visualization tool. Furthermore, it shows that the formative assessment strategy of sharing, clarifying and understanding learning intentions and success criteria related to 21st century skills in the context of real-life design projects supports self-evaluation and feedback uptake.

Keywords

Sharing and clarifying learning intentions, formative assessment, divergent thinking, primary education, brainstorming, self-evaluation

Introduction

Combined with the growing need for creativity in many occupations, policymakers, companies, educators and parents find it important that education cultivates creativity. Design and Technology activities are an excellent vehicle to develop creativity (Barlex, 2007; Klapwijk, 2017; Benson, 2017). Through an iterative design process, students learn to develop original and relevant solutions.

However, although design activities have the potential to stimulate learners to develop creativity and other 21st century divergent thinking skills, this potential is often not achieved. Schut, Klapwijk, Gielen, Van Doorn and De Vries (2019) observed design fixation among primary

school pupils, while Lindfors, Heinola and Kolha (2018) concluded that avoidance oriented students tend to avoid developing solutions during a design challenge.

Formative assessment could support the learning process during design projects as it is meant to directly influence the learning process. It is defined as "*any assessment for which the first priority in its design and practice is to serve the purpose of promoting students' learning"* (Black, Harrison, Lee, Marshall, & Wiliam, 2004, p. 10). Important is "*the process of seeking and interpreting evidence for use by learners and their teachers to decide where the learners are in their learning, where they need to go and how best to get there*" (Broadfoot, Daugherty, Gardner, Harlen, James, 2002, pp. 2-3). Formative assessment has profound learning gains especially when teachers include strategies for sharing, clarifying and understanding learning intentions and success criteria (Wiliam 2018; White & Frederiksen,1998).

Five key-strategies for formative assessment should be used in an integrated way (Wiliam, 2018):

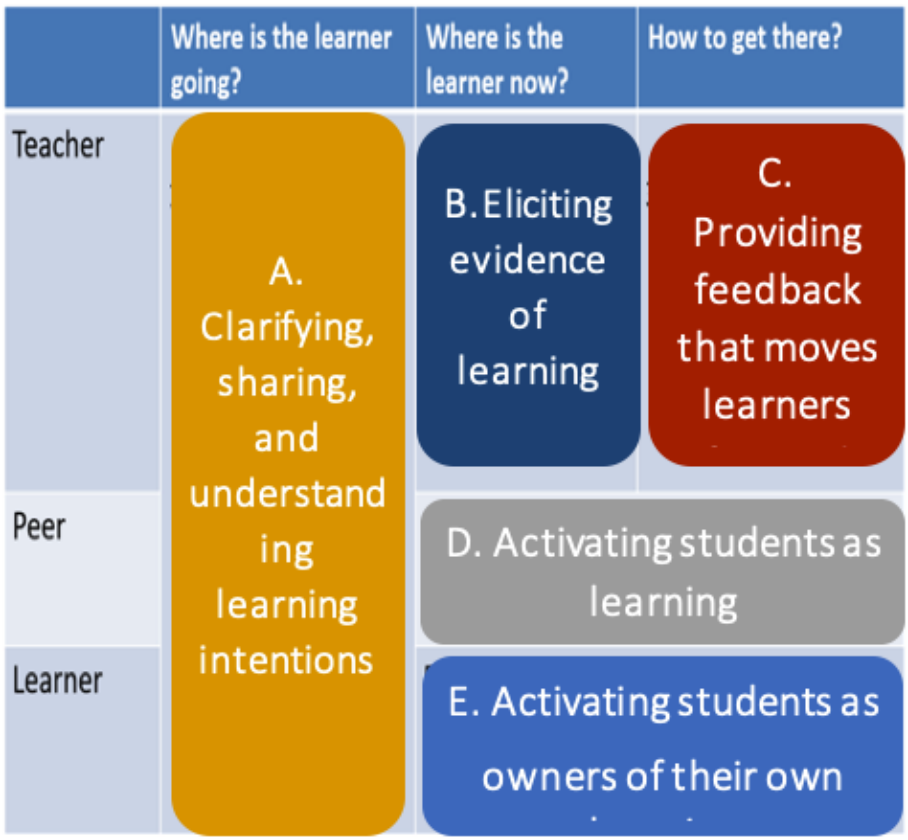


Figure 1. Five key-strategies for formative assessment (Wiliam 2018).

In the context of authentic design and technology projects, many of these formative assessment strategies have been developed. To elicit the unpickled design process (strategy B), e-portfolios affording multi-modal responses (text, drawing, photo, audio) have been used. Initially, these e-portfolios were used for summative assessment, but soon the rich evidence was applied formatively enabling teachers, students and peers to reflect on the design process and (intermediate) outcomes leading to timely feedback (strategy C and D) (Davies, Collier, & Howe, 2012). Peer feedback was also central in Adaptive Comparative judgement (ACJ)

approaches in which students compare design outcomes one by one in an holistic way (Bartholomew, Strimel, Yoshikawa, 2019; Seery, Buckley, & Delahunty, 2019). As a result of providing peer feedback, students developed a nose for quality and were better able to judge their own design outcomes (Seery et al. 2019). Various formative assessment studies have focused on supporting teachers in eliciting evidence through thought-provoking questions that help students to assess the value of their designs and to organize their design processes (Stables, Kimbell, Wheeler & Derrick, 2016; Swathi, Fox-Turnbull, Earl-Rinehart, & Calder, 2020).

However, in none of the formative assessment studies found in the domain of primary and secondary design and technology projects, learning intentions and success criteria have been explicated beforehand to the students. In most approaches, students discover the learning intentions only during the design practice. Compton and Harwood's (2003) framework is a positive exception and the described case-studies include sharing specified learning goals beforehand. However, no specific tools were used to achieve a better understanding. As a result, students usually embark on design journeys without a clear vision of the learning intentions.

In design and technology projects, many learning intentions are possible due to the 'whole task approach' ranging from scientific and technological principles, design skills such as creativity as well as practical make skills (McLaren, 2007). This is due to the whole task approach, but the complexity of learning to design may easily overwhelm primary school students and this hinders learning (Looijenga, Klapwijk & De Vries, 2015). A similar problem is noticed in higher design education (Van Dooren, Boshuizen, Van Merriënboer, Asselbergs, & Van Dorst, 2020). Students are just practicing design without learning to design because design skills and certain ways to move through the design process are not clarified. Van Dooren et. al. developed an approach to explain central features of the design process that need to be learned.

In primary schools, formative assessment strategies focusing on sharing, clarifying and understanding learning intentions in the context of real-life design and technology projects are needed. At the Delft University of Technology, a formative approach called "Make Design Learning Visible" was developed, including four tools for clarifying, sharing and understanding design skills (strategy A in figure 1). A case-study was conducted and used to explore how a primary school teacher used an interactive visualization tool to create a dialogue on the learning intentions and success criteria related to divergent thinking in a class with 10 to 12 year old's. Next, students practiced divergent thinking during a brainstorm followed by class discussions in which they reflected on divergent thinking and were given the opportunity to apply the feedback in a second brainstorm round.

The main research question is: *Which factors contributed to successful clarifying and sharing of the learning intention of divergent thinking and under which conditions does this support students in assessing and changing their divergent thinking behaviour?"*

The outline of this paper is as follows. In the next section, the benefits of sharing, clarifying and understanding learning intentions in design and technology projects is described. Following this is a section that explains the decisions made in the development of "Make Design Learning Visible" approach and how learning intentions related to 21st century skills have been formulated. The research methodology is then described, followed by results and conclusions.

The value of sharing, clarifying and understanding learning intentions

Many researchers consider clarifying and sharing learning intentions and success criteria foundational to formative assessment (Wiliam, 2018; Gulikers & Baartman, 2017; Wylie & Lyon, 2015). Empirical studies indicate that teachers who do well in clarifying learning goals, are also more effective in the subsequent stages of the formative assessment cycle (Gulikers & Baartman, 2017).

Sharing, clarifying and understanding learning intentions is important for the formative assessment process as a whole and influences the four other strategies. Students are not automatically on the same page as their teachers and may have different ideas about what they are learning, or they have no clue at all as Gulikers & Baartman (2017) conclude in a meta-analysis referring especially to four studies (Bloxham & Campbell, 2010; De Lisle 2015; Hogan, Towndrow & Koh 2009; Newby & Winterbottom 2011). Explicating learning intentions will raise the participation of students in the formative assessment process as clear intentions enable them to monitor their own work as well as to assess the work of their peers (White & Frederiksen, 1998). Students can learn more independently once they know the success criteria in a tangible way. They are able to practice design and learn from it without direct support as self-correction is possible. This also stimulates ownership of learning.

Research shows that around 50% of the learn- and feedback activities of teachers are not related to the learning goals (Moss, Brookhart & Long 2013). Explicating learning intentions and success criteria beforehand provides a focus for eliciting evidence and feedback. In real-life tasks such as design and technology projects, understanding the learning goals might even be of greater importance as learners may become easily overwhelmed by the amount and complexity of possible learning intentions (Looijenga, Klapwijk & De Vries 2017; Van Dooren et al. 2020). This is due to cognitive overload when performing real-life tasks without substantive support (Van Merriënboer & Kirschner 2018).

McLaren (2007) also states that clarity is needed on the learning intentions and indicators of progression and advocates multi-dimension assessment in design and technology education. Teachers – especially those in primary and secondary education who are usually not designers - need to know what to look for when they formatively assess. In Dutch primary classrooms we experienced that assessment tends to focus on cooperation and communication, and not on any of the other 21st century skills. A similar problem is prevalent in peer assessment practices in a design project described by Bartholomew, Strimel and Yoshikawa (2019). Here, secondary students tend to comment mainly on the appearance of the designed posters and hardly on other qualities such as empathy or creativity. All parties involved in design and technology projects, need to understand what the learning intentions are and how quality looks before they practice and assess design learning.

“Make Design Learning Visible”

The Delft University of Technology and its partners developed the “Make Design Learning Visible” approach (Klapwijk, Kok, Visschedijk, & Holla, 2017; Klapwijk, Holla, & Stables, 2019) that aims at formative assessment of design skills.

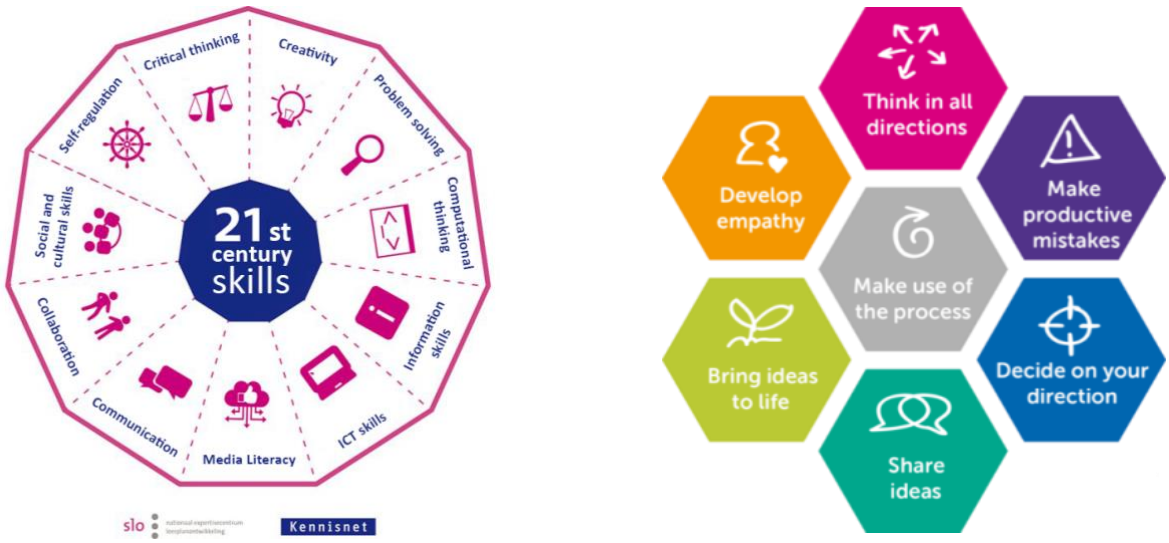
Formative assessment experts in design and technology education have advocated a process-based approach instead of a product-based approach (Kimbell 1997; Fox-Turnbull, 2006) as the process reveals more about the learning process. However, case-studies on these process-based formative assessment approaches show that feedback tends to focus on what steps to take next in the design process (Kimbell, 2012; Swathi et al. 2020).

We therefore choose to focus our approach on 21st century skills, these are generally associated with higher order skills and behaviours that represent the ability to cope with complex problems (Voogt, & Pareja Roblin, 2012), see the example in figure 2. Although 21st century skills are not the only goal, they are at the core of what students should learn from designing. Each skill would invite teachers and students to look with a specific angle to the design process and its outcomes. Aspects for assessment are isolated while practicing the whole task, e.g. distinguish between the quality of creative thinking, cooperation or information seeking.

We assumed that assessment of 21st century skills enables focussing on the learning process because isolating specific skills in a complex design process will stimulate the kind of diagnosis and specific feedback that moves the learner forward. This approach in formative assessment is relatively new in the context of design and technology projects but similar to the one Frederiksen and White (1998) applied in the context of inquiry based learning. They focused assessment on a limited number of research skills, introduced these two at the time and students are asked to reflect on them after each research task. This was highly beneficial for the development of these research skills and knowledge growth accelerated as well, in comparison to the control group, especially for students who had low scores in literacy and numeracy.

In developing the descriptions of the skills, we had to balance between being too general and being too specific (Aschbacher & Alonzo, 2006; Torrance 2007). When a learning intention is too specific and includes the context, it cannot be transferred to other situations (Clarke 2005; Wiliam 2018). Teachers often make the mistake of sharing learning intentions in a contextualised way, for example, students are told that they need to be able to analyse a questionnaire about movie-going habits. However, the real learning intention is that students can analyse questionnaires on any topic. Therefore learning orientations have to be formulated in a context-free way.

21st century skills are context-free; however we judged that they would be too broad for self-monitoring. We therefore decided to translate the 21st century skills to more concrete design skills. To help teachers and students, an overview is needed which is relatively simple to remember and easy to use. This resulted in seven key design skills (Klapwijk, Kok, Visschedijk, & Holla, 2017; Klapwijk, Holla, & Stables, 2019) (see figure 1 and Appendix 1). Although these seven design skills are in line with the literature design, they could have been selected differently.



21st century skill		Design skill
Creativity		Think in all directions
Problem solving		Bring ideas to life
		Make productive mistakes
Communication		Share ideas
Collaboration		
Social and cultural skills		Develop empathy
Self-regulation		Make use of the process
Critical thinking		Decide on your direction
Information skills		
Computational thinking		Depending on the theme
ICT skills		
Media Literacy		

Figure 2. Relating design skills to 21st century skills of the Stichting Leerplan Ontwikkeling (SLO) and Kennisnet model

In figure 2 the design skills are related to 21st century skills formulated by the Dutch curriculum organization SLO. Creativity is quite a catch-as-catch-can concept and is too general for guiding assessment. The hexagon model therefore divides creativity into: 1) thinking in all directions (divergent thinking), 2) making ideas tangible (converging thinking) and 3) making productive mistakes. In creative processes, two cognitive processes are important, divergent and convergent thinking (Howard-Jones 2002; Goldsmidt, 2014). Divergent thinking is generative in nature and entails the generation of new thoughts, ideas and perspectives, while convergent thinking is evaluative in nature and entails reflection of these thoughts, ideas and perspectives (Sowden, Pringle, & Gabora, 2015). In addition, as creativity is stimulated by experimenting and iterating (Looijenga et al. 2015), "make productive mistakes" was isolated as skill. Skills related to inquiry and research are also relevant for design, but a separate set was developed, these are not discussed in this article.

None of these design skills is tied to a specific stage in the design project. Each skill is important all over the design project. As such, they can be used to isolate elements of the design practice and lead to specific feedback. Evidence for the functioning of a skill can be derived from various sources: the process, the product, the person and it is also possible to collect information about the press that influences skill development. Press relates to everything surrounding the creative design process and ranges from school culture, design tools, teachers, peers to physical surroundings. This rich approach to evidence collection was inspired by the 4P-model of Rhodes and is described in detail for assessment of creativity in the International Handbook of Technology Education (Klapwijk, 2018).

Nineteen tools were developed to make all five strategies of formative assessment feasible (see Appendix 2). Four tools focus on clarifying, sharing and understanding design skills and success criteria;

1. *Practice your skills*: skill cards support students to understand design skills, see figure 3.
2. *Symbols for design learning*: design learning symbols such as or are used to show students which skill they are developing
3. *Evaluate examples in advance*: learners analyse and discuss examples of design projects to discover success criteria beforehand.
4. *Visualize a design skill*: students explore in images and text what you have to do when you apply a design skill successfully

Figure 3. Skill card explaining divergent thinking (Klapwijk et al., 2019)

Using examples before students embark on a new project is a well-known strategy in formative assessment, often applied in the context of language learning (Hawe & Dixon, 2014). At first

sight, it looks similar to ACJ, however, students discuss anonymous examples from another class and compare good and less good examples of a specific design skill.

As the tool "Visualize a design skill" is rather innovative and we wanted to know if it helped to clarify learning intentions and how it supported the other formative assessment strategies. Our research question is "*Which factors contributed to successful clarifying and sharing of the learning intention of divergent thinking and under which conditions does this support students in assessing and changing their divergent thinking behaviour?"*

Methodology

An explorative research design was applied because knowledge on using visualization to involve students in clarifying learning intentions is not available. A qualitative case-study was carried out to gain a first insight in the underlying mechanisms of the tool and develop suggestions about strategy A (figure 1) in design projects.

Participants

A Dutch school participated with a class of 11-12 year old's. The participating school is, 'development-focused', meaning that umbrella themes are used to integrate different learning subjects over the course of a few weeks. The students were accustomed to collaborate in teams over a longer timeframe on a range of educational activities. The class was divided in gender-mixed design teams of four students by the teacher. The teacher had been involved in an earlier research project on the same design project, however, it was her first time to facilitate a complete design project.

Design problem and sessions

The students were asked to design new activities for the gym of the future in a design approach based on the Creative Problem Solving model (Isaksen, Dorval, & Treffinger, 2010; Tassoul, 2009) in which divergent and convergent activities alternate. The educational approach has been described earlier in a study with different students (Schut, Klapwijk, Gielen, Van Doorn, De Vries, 2019). In six sessions (1.5 hour each), teams explored the design problem, generated solutions and elaborated these solutions (figure 4).

Formative assessment

The formative assessment focused on divergent thinking and two tools from the "Make Design Learning Visible" approach were used: Visualize Design Skills" and "On the right track?" "Visualize Design Skills" was used during session 1 for strategy A, students' suggestions on how to think divergently were collected and the class collectively devised symbols to depict the suggestions (figure 4).

Next, students practiced a brainstorm in session 2. During a second brainstorm in session 3, a teacher-led reflection on the process and products of divergent thinking so far was held. After this, another brainstorm round took place to enable students to apply feedback and newly developed insights on divergent thinking. Pausing halfway during an activity to reflect on a specific design skill is part of the toolbox and called "On the right track?" (strategy B and C).

Both tools were explained to the teacher by the second author and she received the toolbox (Klapwijk, et.al. 2017).

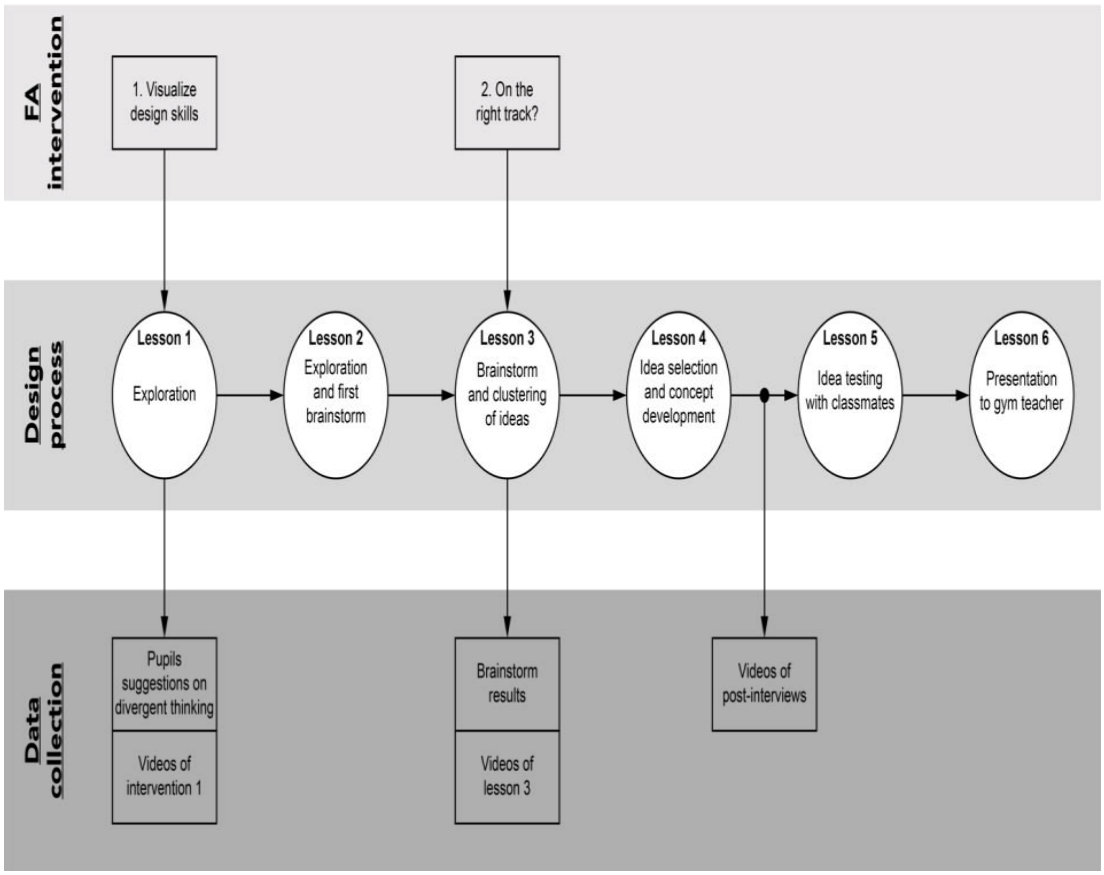


Figure 3. Formative assessment tools, design process and data collection.

Data collection

Audio- and video-recordings were made of the formative assessment activities in session 1 and 3 and transcribed. Two teams that were thought representative by the teacher were specifically followed. Both brainstorm sessions during session 3 were recorded. Fieldnotes were made by the second researcher.

Pair-wise post-interviews with 7 students from the selected teams (1 team member was sick) were conducted a week later focusing on the pupils' awareness of divergent thinking, their experiences during the teacher-led pause and their ability to assess and change their divergent thinking. The themes in these semi-structured interviews were: understanding success criteria in terms of products and processes of divergent thinking, ability to diagnosis and change own divergent thinking, compare outcomes of the two brainstorm rounds. Pre-determined questions were used for each theme, followed by free-following questions.

Specific episodes from the videos were shown to obtain an explanation from involved students about what was happening. The episodes were related to students showing signs of formative assessment, e.g. students trying to diagnosis their own thinking process or supporting peers in divergent thinking. Each pair received questions in free-flowing way.

Students' work was collected: the visualized learning goals (figure 5) and brainstorm results from session 3.

Data analysis

All audio- en video-recordings were transcribed. The data were first analysed by the second author and then by the first author. Guildford's definition of divergent quality (many, varied and original) was applied to assess understanding of and changes in divergent thinking (Guildford, 1967) . The class dialogues were analysed bottom-up using the research question as a guidepost. Indicators to analyse the self-reports were inspired by Guildford.

Results

This section describes the formative assessment interventions and their effect on divergent thinking. The results of the post-interviews are presented to clarify how students understood the goals and success criteria of divergent thinking and applied it to their own thinking processes during the brainstorm.

Visualize divergent thinking

At the start of the design project during session 1 the learning intention was visualized. On a smartboard, an empty matrix is shown and teacher Katy tells her class that they will generate design ideas for the gym of the future next week and asks "*What do we need to do when we think in different directions*?" Subsequently ten proposals are made by nine different students and transformed in eight icons, see figure 4. We selected a number of representative dialogues to show how the learning goal is clarified. Verbal utterances are often ungrammatical, this is also present in the English translation.

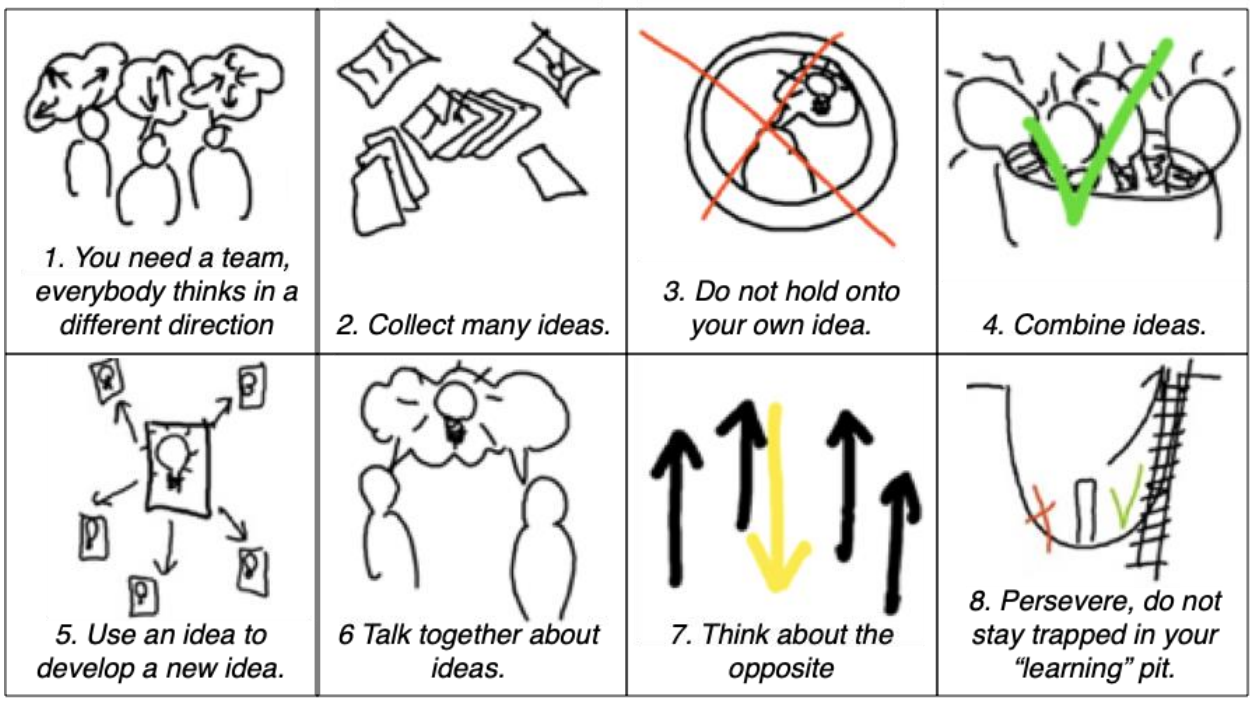


Figure 4. Icons

P1. First proposal

1. Teacher: “Think in all directions.”
2. Anna: “Yes.”
3. Teacher: “What do you have to do for this?
4. Anna: “You should just a little bit…. well…. how do you say this….eh you should think of what you want.”
5. Teacher: “Think of what you want?”
6. Anna: “Yes, well agree which each other. A little bit…”
7. Teacher: “Agree which each other. Are you still thinking in all directions? When you all have to agree?”
8. Anna nods vehemently no.
9. Teacher: No, not so much.
10. Teacher: “But it does help us, because you started hands are being raised over there. It is very good that you started.”

The teacher acts as a gate-keeper and Anna and the teacher decide that agreeing with each other does not belong to divergent thinking. A misconception is tackled. The teacher creates a safe environment by acknowledging the value of Anna’s contribution.

P2. Second proposal (Icon 1)

1. Evelyn: “Well, you all have just…… because when there are more people in your team, you will all have different ideas. As a result everybody will think in a different direction, something like that.”
2. Teacher”: “Well, for thinking in all directions you need to have more people involved. You need your team members. OK.”
3. Evelyn: “Yes, I think so.”
4. Teacher: “How can we…do we think that this is handy? Is Evelyn right when she says, when you are with more people, you will generate more ideas.”
5. (several students show in their behavior that they agree)
6. Teacher: “How can we show this in a little drawing…who has a small idea for this? That you need more people?”
7. Pupil 2: “A few little men.”
8. Teacher: “A few little men.”
9. Pupil 3: “About four of them.”
10. Ella: Yes! With little arrows above their head. (Suggestions by other students at the background, inaudible at the recordings)
11. Teacher: “A few little man…. and a cloud representing the idea. That is what you said. It (referring to her drawing) looks like a wood. With arrows…because they all think in different directions, is that what you meant Ella?”
12. Ella: “Yes.”
13. Pupil 4: “They all think in different directions.”
14. Teacher: “OK. There are more of them and they all think in a different direction.”

The teacher rephrases and checks the idea with Evelyn and the whole class, thus stimulating active involvement of everybody. The drawing of the advice evokes even more active participation, many students are involved in co-developing the picture.

P4. Proposal 4 (Icon 3)

1. Allard: “One person tells I want this and another that…and we say to each other OK we don’t bother we just do one of them. I mean, we should (instead) take my idea and mix it with Tom’s idea and then…”
2. Other pupil interrupts: “Throwing everything together
3. Teacher: “Oh…”
4. Allard: “And then a new answer will hatch and …”
5. Teacher: “You did some good thinking.”
6. Allard: “Mix everything.”
7. Teacher: “So, you say let’s share ideas to let something new originate. You are thinking, this is very handy, so you should not stick to your own idea. Actually you say two things, your own idea, we can maybe make a drawing of this, don’t stick to your own idea and bring all idea’s together, because good ideas can yield even better ideas.”
8. Teacher: “Let’s start with the first drawing, don’t hold on to your own idea, how can we draw this? Mary?”
9. Mary: A traffic sign with your own idea and next a cross, something like that.”
10. Teacher: “So.”
11. Mary: “So you will not only focus on your own idea”
12. Teacher: “Should it be a prohibition traffic sign?”
13. Mary: “Yes.”
14. (other voices at the background indicating agreement)
15. Teacher: “One person with an idea on the sign.”
16. Pupil 1: “Yes, a little man.”
17. Teacher: “OK.”
18. Pupil 2: “And a cloud of thinking with a traffic sign in it and next a cross.”
19. Teacher (*while drawing*): “Don’t hold on to, forbidden, this should be red, a little man*, plieng, plieng (making sounds)*, he doesn’t have a neck…with a light bulb*, tjup tjup tjoeps, plieng, (making sounds)*. So this is a prohibition traffic sign.”
20. Mary: “It needs a cross.”
21. Teacher: “It also needs a cross…a cross, to be clear.”
22. Pupil 3: “Red.”
23. Teacher: “Ready, don’t hold on to your own idea.”
24. Students are laughing.
25. Some-one (maybe contributor Allard): “And mix everything.” (Class continues to develop icon 4)

This dialogue shows that visualizing is engaging for students. The teacher invites everybody to suggest drawings, draws out loud, paraphrases and uses suggestions on the fly. Idea’s for drawings come mostly from students that were not the one coming up with the advice. When Allard suggests that one should not hold on to one’s own idea, Mary proposes to use a traffic sign. The use of drawings provides room for the teacher to repeat ideas (P4, line 19). The students develop their own vocabulary, “to mix everything” and the image of a “cooking pot” for randomly combining ideas (icon 4).

Other proposals follow and Katy takes time to elicit the idea. She either repeats the key-idea in exactly the same words of the contributor (P1, line 5), or she rephrases the idea in her own words (P4, line 7). She often checks with the contributor if she understands the idea right (P2, line 2). At one point, a girl has difficulties explaining her idea to the class. But the rephrasing by the teacher and the subsequent visualization proposals of her peers result in a shared understanding.

At the end of the activity, Lana voices a misconception as she confuses divergent and convergent thinking. The teacher helps her to understand the difference between the two.

P8. Proposal 8 (No icon)

1. Lana: "Maybe make one big idea with your team."
2. Teacher: "Have a quick look – what is the skill we are talking about? "
3. Lana: "Yes, OK. "
4. Teacher: "The current skill is about thinking of something good, we will start with exploring all the different alternatives, think in all directions…eventually the goal will be to develop one idea… but this is one step ahead. So, you should keep this idea in mind, however, the idea does not belong to thinking in all directions."
5. Lana shows that she agrees.

This dialogue led to the next proposal.

Proposal 9 (icon 7 Think about the opposite)

1. Thomas: You should try to think in a completely different direction
2. Teacher: A sort of the opposite
3. Thomas: Yes, you should…
4. Teacher: How can we…do you have a drawing in your head Thomas?
5. Thomas: arrows, they are all going in different directions
6. Teacher: So, when we make arrows, I am going to make them a little bit thicker. We all think a bit like this (drawing arrows in the same direction), we all have ideas in this direction, it would be fun if we turn one idea completely around. Think in a completely different direction for a moment. Excellent.

Visualization of the proposals pulls many students into the dialogue and co-development of the learning goal.

The way the teacher leads the dialogue creates a safe climate and involvement of many students. She repeats ideas in exactly the same words or rephrases idea's and keeps checking if she understood the students. She acts as a gatekeeper for misconceptions (P1, P8) and this evokes further clarification (P2, P9). She sometimes elaborates the idea, but students are the main developers of the advices for divergent thinking.

The developed icons contain much process-related advice (together, combine, do not hold on to your idea, think of the opposite, do not give up, collect many ideas). Also, the kind of outcomes one looks for become clear (many ideas, variety, new ideas resulting from combinations). Elements related to press are prevalent (with a team).

Brainstorm in two rounds using "On the right track?

Groups of four students work together in the design project and each of them had generated a specific design assignment within the theme of physical education. The teacher asked the students to brainstorm individually, write and draw their ideas on small sheets of paper. The first four minutes they came up with ideas were without any other support followed by ten minutes in which they used pictures pulled out randomly from a shared envelope. A few episodes were present in which students' diagnosis their own or peer brainstorm activities or provide feedback.

Lana is speaking out loud during her brainstorm. Lianne, from the same team, reacts:

1. *Lana: "I am continuously (thinking) about dodgeball."*
2. ……..(other comments)
3. *Lana: "Dodgeball, dodgeball, dodgeball."*
4. *Lianne: "Lana, empty your head for a minute, because you only think about dodgeball."*
5. *Lana: "What?"*
6. *Lianne: "You think only about dodgeball."*
7. *Lana: "Yes, yes, I know"*

Lianne realized Lana's fixation on dodgeball when she heard Lana speaking out loud to herself. She also noticed that Lana filled many idea-cards with dodgeball ideas. Lianne 's diagnosis and feedback helped Lana. In the post-interview, Lana reports that from this moment on she started to think in a different direction and changed her current picture for a new one.

Danique from the other videotaped group is able to diagnosis her own situation. When we show her video fragments of the first round, she explains that she, after a period of being absent minded, realized that she was not able to come up with ideas: "*Well, I didn't really understand the meaning of the picture. And I was not really able to connect an idea to it (the picture) …I was thinking about a rugby ball, but then I was thinking…. well, rugby in a gym is maybe not a very good idea*" Although Danique realizes that she was not able to write down her ideas, she was not able to adapt her approach.

On the right track?
The teacher pauses the brainstorm to have a class dialogue to diagnosis and assess the divergent thinking so far. She starts with a series of questions about the amount of ideas and the variety of ideas, applying Guildford's criteria. "I *have a question about thinking in different directions. Take some time to think about this. Did you (plural) come up with many ideas?"*

Many students react, and a loud 'yes' is audible. Next she asks the students about variation in ideas:

1. Teacher: "*Did you (singular) succeed in coming up with different ideas?"*
2. Denise: *"I first thought of a tag game, after that I came up with a ball game and then another ball game."*
3. Teacher: "*Can you explain why you succeeded? "*
4. Denise: *"Because of the images."*
5. Teacher: *"The images helped you this think in a different direction, a new kind of game."*
6. Lana: "*When you had a picture and did not know what to do, you could look at other pictures and I combined these*."
7. Teacher: "*Oh yes, I immediately get an icon in my head, from one idea to another."*

The probing question (line 3) and her paraphrasing (line 5, 7) help the students to elicit the processes that made them successful.

Later, another girl compares her brainstorm with and without pictures and explains that she had great difficulties in coming up with any ideas at the start of the brainstorm. This makes Joris

suddenly realize that he was fixated and says: *"Because I had been busy with the topic yesterday, I stayed stuck to this topic the first three minutes. I thought of a new idea that could go with it, but then, I kept holding on to what I did yesterday."*

Joris explains in the post interview: *"I realized this (the fixation) during the pause, because the teacher said something like "How did it go? And then I thought, I was too much engaged with my idea from yesterday."*

The teacher evokes more responses and asks: "W*ho recognizes this*?" Approximately half of the class holds up hands to indicate that they experienced the same problem. As such students became a learning source for each other (strategy D) and learned from each other's diagnosis (strategy B).

Usually, teacher Katy initiates a dialogue, but in the example below a student who worries about her brainstorm results, starts a dialogue.

1. *Danique; "I thought eh…because many children said that it should be games. I thought we did it wrong."*
2. *Teacher: "What was your design assignment?"*
3. *Class: "Oh…" (surprised).*
4. *Danique: "Eh…a game for physical education."*
5. *Other pupil: "For teams."*
6. *Another pupil: "Design a new game for physical education that helps to select a team."*
7. *Teacher: "Ok."*
8. *Danique: "Did we have to relate to it (the brainstorm to the question)?*
9. *Teacher nods.*
10. *Danique": "Some of our ideas match, I suppose."*
11. *Teacher: "Ok. So your approach was more broad than the design question. Maybe I should have made it more clear."*

Through the questioning of teacher Katy (line 2), Danique and a number of other students start to understand that the specific design assignment is important for the direction of the brainstorm.

Next, a summary of what went well and of things they could change is assembled. The class develops various advices to forward the divergent thinking process, e.g. a team mentions that they want to focus more on the design question. Danique, the girl who knew she was fixated during the brainstorm, suggests "Don't stick to your idea." The teacher gives one suggestion:

1. *Teacher: "I was walking past by one of the teams and they were writing their ideas down and I then told them that they were allowed to draw as well. The day before this was a question that was often posed: Should I write or should I draw. …..*
2. *Pupil: "I did both."*
3. *Teacher: "You just did both. That is fine. But when I passed someone who heard "I am allowed to draw as well", she went like a rocket and suddenly it was a lot easier to proceed. "*

The refection halfway through the design activity was based on the tool "On the right track?" and enabled students to collectively elicit and diagnose divergent thinking. They identified the

power of the using pictures as well as the occurrence of fixation. The icons and the criteria of many and varied formed a reference point. Also, a new success criteria was discovered, you need to generate ideas that relate to the design question. After this, a second round of brainstorming of 10 minutes was organized using random pictures as inspiration source.

Self-reports on divergent thinking

Below the results of the post-interviews are given.

Insight in outcomes of divergent thinking

All seven interviewed students have captured the idea that one needs to think of many ideas.

Danique:	"Yes, Yes, you have to …. Ok, not hold on to your own idea and …you should not one, but generate many ideas."
Interviewer:	"How many?"
Danique:	"As many as possible."
Interviewer:	"OK, not hold on to your own idea. Generate as many ideas as possible. Anything else?"
Danique:	"Ehm.."
Interviewer:	"What did you mean with "Don't hold on to your own idea'? "
Danique:	"Well, eh…also…you have to be open for ideas for other people. And not just perceive only your own idea as being good. "

The post-interviews show that they all understand having varied ideas is important. For example, a pupil explains that she had first an idea with a ball game and next an idea about dancing, or first an idea for a small group of players and then an idea for a big group.
They also know that divergent thinking is about having new ideas. Most students use the term new in the sense of an idea that they as a person or group did not have the idea before.

The idea combining elements in a new way is relevant, is also known to the seven students and they applied this strategy:

Joris:	"We had also ideas with handball and soccer and we developed a sort of …."
Livia:	"Yes, and then …soccer without hands, so you also…."
Joris:	"You may use your hands when you are not able to go on, when you are completely locked in, then you can take the ball into your hands and you are allowed to throw it away."

This shows that students understand most of Guildford's criteria of divergent thinking outcomes. However, the idea of having unusual or original ideas was only clear for two students. Denise and Sophie mention this, e.g. "*It should be something that is totally different. For example a piano lowered in the floor, sponges a person can tumble on or a very strange dance battle with a flashlight in the gym*."

The students were able to explain the kind of processes needed for divergent thinking. Quite often, they used expressions from the collective drawings or reflection, e.g. "you should not stick to your own idea" (Danique), "You should think of the opposite" (Livia) and "You and me, for example Joris and Livia, all the best ideas are put in a cooking pot." They also developed a

vocabulary around fixation (“get hooked on to an idea”, ‘sticking to”,) and about getting past fixation (empty your head, reset your mind).

Self-reports on the effect of the visualization tool and the pause

To establish the effect of the pause, brainstorm results from the first and second brainstorm round were compared. The amount of ideas dropped from 32 on average per team in the first round to 16 in the second round. The ideas in the second round are more elaborated, which is according to Guildford a measure of creativity. However, the level of variety and uniqueness of the ideas could not be compared objectively because the ideas were not clear enough to be analysed.

The self-reports given in the post-interviews are summarized in table 1. All seven students mention positive effects of the pause on their second brainstorm. They also refer to specific icons or advises given during the pause. This was mostly spontaneous, but prompted by the interviewer in a few instances.

As described before, Joris realizes his fixation and reports that he was able to change his thinking processes in the second round. Livia mentions that she was able to think divergently in both rounds and she did not notice large differences. However, she started to apply the advice to think about opposites after the pause and the pause helped her to ‘reset” her mind. She also developed new strategy to combine elements: *“I was really running out of ideas as I had used all the picture-cards. And then I picked two picture-cards and laid these near each other. And then I discovered that I could combine these….”*

Lana and Lianne found the pause helpful and used the icons. Nevertheless Lana judges her first round as the one with the most ideas. She evaluates her both rounds as equally good in terms of variation because in the second round she would often think “Oh*, I have this idea thought of this idea already, I have thought of it already, I have thought of this idea already. What should I do now?*

Lianne gave during the reflection her class the tip “to persevere” and applied it herself in the second round.

Lianne:	“Don’t give up.”
Interviewer:	“Don’t give up. How did you apply that in the second round? Or did you apply it?”
Lianne	“Yes, at a certain point I was not able to generate an idea. And I was thinking …what should I do with this picture and then I quickly took a second picture and then I developed a small idea, an idea with it. And I received many ideas, also in combination with the earlier picture.”
Interviewer:	“So you generated new ideas by combining two ideas, do I understand you well?”
Lianne	Yes.”

Denise and Sophie report less ideas in the second round because it was more difficult to generate ideas related to the design question. However, the ideas were more unusual and related to the design question. Informal contact with students who had unusual ideas, made them realize that they should not judge ideas and this allowed them to generate unusual ideas.

Danique reports that she was able to change her behaviour. She worried less and developed more and a greater variety of ideas.

Table 1. Self-report on change in divergent thinking due to the pause

	Specific icons used in second round*	**Comparing first and second brainstorm on criterium varied**	**Example of a specific impact mentioned**	**Effect of the pause according to the student**
Joris	2, 6 and 7	Second is more varied.	Able to forget about earlier ideas.	Positive
Livia	7	Equal.	Thought more often of the opposite.	Positive
Lana	4	Equal.	Only use of icon 4 mentioned.	Positive
Lianne	1, 4, 7 and 8	Second is more varied.	Able to persevere which results in a new strategy for divergent thinking.	Positive
Denise	8	Second is more varied and more geared towards the design assignment.	Focus divergent thinking on design assignment.	Positive
Sophie	8	Second is more varied and more geared towards the design assignment.	Focus divergent thinking on design assignment	Positive
Danique	8	Second is more varied.	Able to worry less during brainstorming resulting in a behavioural change with respect to picking new pictures	Positive

Note: * explicitly mentioned

Each pupil referred to specific icons that they used during their brainstorm, usually during their second round. Although advice three and five were not explicitly referred to, the interviews show that the students had internalized them. All students report a lower ideational fluency (amount of ideas in a certain time period) at the end of the second brainstorm as they had already used all pictures from the envelope.

Five students judge their second brainstorm as more varied. Livia and Lana report no change in this quality. However, each pupil reports a positive change in divergent thinking due to the visualized learning intentions and the reflection during the pause.

Conclusions and discussion

Visualization of the proposals and way the teacher led the dialogue led to co-development of the learning goal of divergent thinking. This led to an increased understanding of the goal of divergent thinking and students could explain the learning goal of diver gent thinking using their own vocabulary, as well as icons and ideas developed in the class dialogue, which indicates an internalized and comprehensive understanding.

Several factors contributed to the co-development and internalization of the success criteria for divergent thinking. *The visualization of each advice* led to active involvement of all students. This allowed them to think deeper about the learning intention as they thought (collectively) of suitable icons that would explain how sound divergent thinking looks. The tool allowed for the development of their *own vocabulary, both in words and pictures,* e.g. “mixing ideas” for the process of connecting seemingly disparate ideas.

The visualization process led to a *balanced involvement* of the teacher and the students. Although all advice was coined by the pupils, the teacher guided the students towards a sound sense of quality, for example by sharing information about the outcomes of divergent thinking and by exposing misconceptions.

Whenever misconceptions were voiced, the teacher acted as *gate-keeper* by asking if certain suggestions really led to divergent thinking. As a result, students were able to think their advice over. *Exposing misconceptions* is not common when learning intentions are shared. However, knowing what one should not do is also extremely important as we know from experiments in the tradition of behavior modelling, people who are given both good and bad examples during a training perform better, especially in daily practice (Kitsantas, Zimmerman, & Cleary, 2000; Baldwin, 1992).

Quite often, learning goals are shared by teachers without it being clear whether students understand them (Gulikers & Baartman, 2017). The visualization of each contribution gave the teacher the *opportunity to check if the shared success were clear* to the class. In this class, *good conceptions of divergent thinking* were present amongst students and these were collected and clarified for everyone. We assume that made the success criteria relevant and understandable. *The way the teacher guided the sharing of advices*, taking time for *paraphrasing, asking, elaborating ideas and involving the whole class*, resulted in a *shared* framework. This is especially clear from the post-interviews in which the students refer to the icons and use vocabulary from the pause.

All students interviewed developed a sense of quality and used this to forward their divergent thinking process in the first round and even more so in the second round. Of course, they have not yet a complete insight in how sound divergent thinking may look, e.g. the concept of originality was not clear to most of them. There are thus limitations to the use of the tool “Visualize a design skill.” When students generate success criteria for a skill, some elements may be underrepresented. However, this does not have to be a problem, as teachers can clarify these unknown aspects in another design activity. According to their own perception, the majority of the interviewed students were able to use the collective diagnosis and feedback to improve their divergent thinking. Although the reported change did not always have a huge

impact on the quality of the brainstorm results, it was always an important step forward in developing adequate divergent thinking behaviour.

The feedback uptake is remarkably effective, compared to what is known about feedback, e.g. students ignoring feedback or other adverse reactions (Wiliam ,2018; Dweck, 1975; Kluger, & DeNisi, 1996) and in design education (Schut et al. 2019; Troxler, & Klapwijk 2018).

An explanation could be students were the *main contributors in the diagnosis and feedback activities*, the input of the teacher was limited. Successful teachers tend to *allow more student steering* during the discussions, reacting on what students say (Buck, TrauthNare &, Kaftan, 2010, Ruiz-Primo, & Furtak, 2006; Ruiz-Primok & Furtak, 2007). This is what the teacher did, students came with the issue of fixation and with relating a brainstorm to the design question. The self-diagnosis shared stimulated the meta-cognitive thinking of other students as they recognized similarities as well as differences when comparing their divergent thinking processes with those of other students.

There was f*reedom* to pursue different approaches to divergent thinking. Each icon was an advice that could be used, but not necessarily something that one had to do. Students could thus select and use the icons and feedback advice that was relevant for them and neglect others. We also assume their specificness led students to the hope that they were able to change their thinking process.

The focus on one design skill and the limited numbers of advice (8 icons) made the diagnosis and feedback manageable. It is clear that students in the second brainstorm round focus on improving only one or two elements that are relevant for them. Many studies indicate that self-assessment and peer-assessments are strong instruments as long as the teacher structures and steers the assessment (Restrepo, 2013; Willis, 2011; Wylie, & Lyon 2015), this is exactly what teacher Katy did as she used the product-criteria (many, varied, new) and the process-icons to structure the reflection.

Our case study emphasizes the value of enabling students to develop their own terminology as a way to engage them in assessment. The research results indicate that using a visual tool to clarify and share design goals in an interactive way is very beneficial and creates a good foundation for self-assessment in a collective setting. This happened in one class with one specific teacher who is strong in allowing student steering. Additional quantitative research is needed and objective comparisons of the generated ideas before and after interventions.

Our case study shows how clarifying, sharing and understanding learning intentions related to design skills during complex design and technology processes (strategy A) provides a foundation for the next four formative assessment strategies were students elicit evidence (B), diagnosis their own progress with respect to a specified design skill (B) and use feedback to move the learning forward (C). Learners were a source for each other (D). And as they personally selected something to become better in during the second brainstorm, they became owners of their own learning (E).

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Appendix 1 Overview of design skills

An overview of the design skills used in "Make Design Learning Visible" that were formulated for teachers are given. These skills are also described for students on cards using pupil friendly language.

THINK IN ALL DIRECTIONS

Students generate many, diverse and original ideas. They combine, associate and imagine. They seek inspiration in unusual places and look at problems from different perspectives. And most important, they postpone their judgement.

› **Many** – come up with a lot of relevant possibilities, solutions and ideas.

› **Diverse** – think from different viewpoints and try out various directions

› **New connections** - associate, combine and make new connections.

DEVELOP EMPATHY

Students empathise with and understand other users. They experience the problem themselves, investigate the users and context and actively seek input and feedback. They focus on the user's wishes.

› **Experience** - Experience the problem yourself, identify yourself with the problem, users and stakeholders.

› **Target group** - Research the user and context through field research and use the findings in their design process.

› **Active** - Involve users and stakeholders in their design process and actively seek input and feedback (context mapping, co-creation, testing).

BRING IDEAS TO LIFE

Students express and elaborate their thoughts and ideas in appropriate, meaningful ways and use tools such as stories, drawings, models and prototypes. Making ideas tangible is not only essential for sharing them, it is how you think and learn.

› **Express** - Depict ideas and insights for yourself and others.

› **Develop** - Make ideas as concrete as necessary in order to share them and make decisions.

› **Model** - Use media related skills, including drawing, visualisation, drama, storytelling, simulation, modelling, (prototypes) making and computer programming.

SHARE IDEAS

Students share their ideas and collaborate within their team. They involve users and other stakeholders in their design process and they look for collaboration with people outside the process to improve, spread and implement their ideas. They design together.

› **Letting go** - Share your own ideas: find the balance between letting go and staying true to an own idea

› **Complement each other** – Be open to each other's ideas, complement and help each other.

› **Outward** - Involve people with various backgrounds (inside and outside the process) for feedback, support and guidance. Inspire others.

DECIDE ON YOUR DIRECTION

Students organise their ideas and develop an overview of their project. They form an opinion about the essence of the problem and the desired quality of the solutions. They decide on their design direction.

› **Validate** - Form your own opinions, dare to make value judgments, aim for your ideals and take balanced decisions.

› **Overview** – Order all the generated ideas and information collected to provide an overview and use this to make decisions on the design direction.

› **Focus** - Determine your vision, focus on the core and draw conclusions

MAKE PRODUCTIVE MISTAKES

Students try out- at the earliest possible stage - their beliefs, ideas and solutions. They deliberately apply different approaches, techniques and resources. They iterate and use mistakes to learn from.

› **Try out** - Try out as many things as fast as possible. Search deliberately search for mistakes and deficiencies.

› **Learn from mistakes** - Recognize and acknowledge failures. Investigate, comprehend failures and use them to improve and learn.

› **Deal with frustration** - Learn to deal with uncertainty, ambiguity and frustration.

MAKE USE OF THE PROCESS

Students switch between different ways of thinking within the design process. They steer the process and switch between divergent and convergent thinking, nonconformity and cooperation, abstract and concrete thinking.

› **Process knowledge** – Understand the processes of designing and different techniques. Use these in appropriate ways.

› **Reflection** - Reflect on design processes and use feedback for improvement.

› **Self-knowledge** - Discover and develop own skills, design approach, preferences and most suitable methods for you and your project.

Appendix 2 Overview of tools "Make Design Learning Visible"

Formative Assessment Strategy		Tools	
A.	Clarifying learning goals and design skills	1. 2. 3. 4.	Practice your skills Symbols for design learning: Evaluate examples in advance Visualize a design skill
B.	Eliciting evidence of learning	5. 6. 7. 8.	An extra touch to "show and tell' Photo storyline Student reporter Golden frame
C.	Providing feedback that moves learning forward	9. 10. 11.	Perseverance cup On the right track? What isn't working yet?
D.	Activating learners as resources for one another	12. 13. 14. 15.	Suggestions wall Library of inspiration Students as experts Matrix of skills
E.	Activating learners as owners of their learning	16. 17. 18. 19.	Traffic lights Card about yourself Group design results Obstacle game