Gender roles in team decision-making strategies among secondary students during design tasks

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Abstract

The engineering design process (EDP) influences collaborative learning and decision-making in applying science, technology, engineering and mathematics (STEM) subjects, where individuals consider information to solve real-world design problems. Studies show that gender differences influence strategies of decision-making in small groups during design tasks. This qualitative study uses the reflective decision-making (RDM) model as the main framework to investigate how secondary school students make group decisions during the redesign phase, considering the role of gender. 18 of 25 secondary school students worked in small groups to build marshmallow towers. Data was collected mainly from audio recordings and supported by open-ended evaluation sheets. Thematic analysis was used to interpret the data. Findings indicated that all-boy groups emphasised leadership, and quick task completion, and had an optimistic mindset. In contrast, all-girl groups demonstrated collaborative, supportive, reflective and embodied communication, focusing on iterative process and task distribution. These findings suggest promoting inclusive, supportive and reflective teamwork to enhance decision-making in EDP among secondary school students.

Keywords: decision-making, engineering design process, K-12, gender

Gender roles in team decision-making strategies among secondary students during design tasks

Integrating STEM (Science, Technology, Engineering, Mathematics) subjects in K-12 education allows students to learn in the context of complex real-world problems instead of studying each subject separately (Moore et al., 2014). Engineering design functions as an anchor that integrates STEM subjects to address those problems through a structured design process. The engineering design process (EDP) provides a systematic and reflective approach to support the development of practical solutions (Hallström & Ankiewicz, 2023). It helps students analyse problems, apply scientific concepts and boost their critical thinking and problem-solving skills during their design process. EDP in STEM projects allows students to combine theory with hands-on practice while developing design thinking abilities such as problem clarification, idea generation, modelling, and feasibility analysis (Asimakopoulos et al., 2024; McFadden & Roehrig, 2018; Zhou, 2024). Carroll et al. (2010) describe that design thinking offers a different learning approach by developing students' innovation through hands-on projects stimulating empathy, action, ideation, and problem solving. Adding to this, Zhou et al. (2019) argue that when students interact with their design projects, e.g. through sketches and gestures, they are enacting design thinking, since these embodied communications allow them to come up with new ideas and resolve design problems. The design process is often viewed as an iterative cycle, essential to STEM subjects, where designers repeatedly evaluate and improve their ideas until a final solution is found (Design Process – BBC Bitesize, 2024; Moore et al., 2014).

EDP has several stages that facilitate effective problem-solving. In the middle years programme (MYP) 1 (aged 11-12) design curriculum, these stages consist of: (1) problem identification, (2) ideas development, (3) solution creation with the plan to create a prototype for testing, and (4) evaluation (International Baccalaureate Organisation, 2014). This study

adopts the Design MYP 1 model for EDP because of its alignment with the curriculum and approach to learning skills for solving design problems, such as collaboration, reflection, creativity, and critical thinking (International Baccalaureate Organisation, 2014). This model helps students gather accurate information for problem-solving and understanding their responsibilities when they make design decisions. This design process is relevant for students working in small groups.

However, students face some challenges during the design process, such as dealing with uncertainty, having to choose between different options, dealing with limited information and unclear goals, having difficulty identifying criteria, constraints and requirements that are hindering solution completion, and having inconsistent total design time (Atman et al., 2007; Kaur & Dasgupta, 2020). Crismond & Adams (2012) mention that novice designers often reach a solution quickly without fully understanding the complexity of design problems, e.g. treating them like simple tasks. Since they have to deal with these challenges together, strong collaboration and group decisions are important. Van Mechelen et al. (2014) show that when a group of students get along well, they sometimes hesitate to argue against the ideas of others in favour of group cohesion, which might lead to poor decision-making and complicated designs.

In EDP, the role of gender may influence how boys and girls solve problems and make group decisions. Research shows that boys and girls may support and/or challenge each other's ideas in different ways (Nam et al., 2020). This study aims to investigate how MYP1 students make decisions in groups during design tasks, considering gender differences. The research question is "how can decision-making strategies involve younger students in the design process in small groups, considering the role of gender?"

Decision-making and gender groups

Wendell et al. (2017) highlight that engineering design in K-12 is essentially evidence-based, with students making decisions based on data rather than by trial and error. Jonassen (2012) defines decision-making as the process of choosing one or more satisfying options, to achieve the desired results. It is the most common type of problem-solving, comprising simple to complex tasks, such as assessment, negotiation, command and control. These skills play a key role in tackling complex design problems (Jonassen, 2012). The decision-making process consists of three phases: (1) figuring out the problem, (2) evaluating options, and (3) turning decisions into action (Steffen & Hößle, 2014). For example, students might be able to identify and evaluate issues in different contexts, provide reasoning based on evidence and justify their ideas and choices in groups (Ryu & Sandoval, 2015; Steffen & Hößle, 2014).

Recent studies have shown gender differences in decision-making strategies in small groups during design tasks. These studies investigate group dynamics, participation and argumentation skills that link to decision-making among students aged 8-14 in secondary schools (Nam et al., 2020; Putra et al., 2023; Schnittka & Schnittka, 2016; Wieselmann et al., 2019a; Wieselmann et al., 2019b). For example, students' interactions in single-gender groups differ from those in mixed-gender groups, particularly when it comes to decision-making and problem-solving. All-girl groups prioritise harmony and supportive discourse, while all-boy groups show hierarchy, and base their decisions on scientific evidence. Meanwhile, in mixed-gender group, boys' social negotiation patterns remain the same while girls become less collaborative, more competitive and remain silent (Nam et al., 2020; Schnittka & Schnittka, 2016). Understanding decisions based on gender helps teachers create a more inclusive learning environment, since gender dynamics can influence how students communicate and solve problems as a team.

Wieselmann et al. (2019a) examine the effects of group gender composition on participation and interaction among grade 6-8 students in STEM activities, using Informed Design Teaching and Learning Matrix as a framework. This matrix consists of nine categories, such as generating ideas, decision-making, iterating, reflecting, etc. The authors use qualitative comparisons across group types, using memos and a coding protocol. In the laser security system activity, students implement their knowledge of light to plan, test and improve their designs (Wieselmann et al., 2019a). All groups make decisions based on knowledge and explain their reasoning. All-girl groups show better teamwork and more even participation in design activities than girls in mixed-gender groups or all-boy groups, but all-girl groups show less reasoning for their design decisions (Wieselmann et al., 2019a). The authors highlight the need for further investigation on the impact of gender groups on these activities. Wieselmann et al. (2019a) suggest that teachers should manage tasks and monitor group dynamics to support students' interactions, improve learning outcomes, and promote equity. These insights can help teachers decide on forming single-gender groups or mixed-gender groups, especially if unequal participation arises.

While Wieselmann et al. (2019a) focus on group composition, Wieselmann et al. (2019b) have a different approach. The authors investigate a mixed-gender group and compare how boys and girls (5^{th} grade students) interact and make decisions within the same group during the task of designing an electromagnetic claw game. Their results showed that boys and girls engaged the task differently because of their socialization and experience (Wieselmann et al., 2019b). Wieselmann et al., (2019b) found that boys often took charge in discussions, handled materials, showed leadership, were willing to take risks and competed for dominance. Girls were more likely quiet, hesitant to speak, assist peers, and dominate notetaking without influencing final decisions. Girls also tended to show "good student" behaviour that worked well in structured science lessons, but less so during the engineering tasks. Girls actually

handled materials slightly more often than boys (Wieselmann et al., 2019b). The researchers highlighted that equity remained difficult with boys making most design decisions while girls often assisted their peers. Both genders also experienced frustrations: boys often disengaged with the task or blamed girls, whereas girls felt their ideas were unheard by the group (Wieselmann et al., 2019b). Furthermore, students rarely talked about the actual science during the task. They focused on following steps or finishing worksheets, instead of understanding the concepts (Wieselemann et al., 2019b). This study shows the importance of encouraging deeper scientific engagement among students from an early age. It also reveals that girls may struggle in a mixed-gender group when it comes to decision-making.

Schnittka and Schnittka (2016) examine how 7th grade students collaborate in small engineering design groups. The authors focus on how gender composition and traditional gender roles influence engagement in both single-gender and mixed-gender groups during design tasks after the school. The authors integrate the Studio STEM programme with the curriculum, "Save the Snails, Salamanders, and Other Slimy Creatures". This aims to teach students how different energy sources work by building and testing their own small power generators (Schnittka & Schnittka, 2016). The findings revealed that all-boy groups demonstrated more hierarchies, task-focus, and other-oriented speech than boys in mixed-gender groups. All-girl groups demonstrated more solidarity and collaboration, while girls in mixed-gender groups showed stronger various collaboration styles and achieved better learning outcomes. "Micro-aggressions" were observed in single-gender groups where certain less vocal team members were repeatedly ignored during design decisions, regardless of participation (Schnittka & Schnittka, 2016). This study reveals that gender influences engagement and learning outcomes.

Putra et al. (2023) investigate the role of gender in the EDP classroom (grade 8 students), focusing on collaborative argumentation skills. Students work in single- and mixed-

gender groups to make decisions on how to solve a real-word problem about “heat transfer”. The results indicated that girls mostly initiated discussions but lacked reasoning in support of their claims, while boys were more likely to use data when explaining their arguments. Putra et al. (2023) define cultural factors, such as traditional gender roles (in Javanese Indonesian culture), as reasons that influence the participation of female students. In another study, Nam et al. (2020) examine how gender influences the decision-making process among gifted elementary students when selecting renewable energy sources. The researchers implement three different argumentation models: “social negotiation patterns, collaborative reasoning and critical factors for final decision-making”. Nam et al. (2020) found that girls in all-girl groups were more likely to have supportive discourse compared to girls in mixed-gender groups, while boys showed no difference in social negotiations regardless of group composition. In collaborative reasoning, both genders had similar reasoning patterns and frequency. In final decision-making, girls prioritised safety and avoided options with any risk, whereas boys were more likely to base their decision on scientific evidence while avoiding technically disadvantageous options (Nam et al., 2020).

These studies show that gender can influence decision-making strategies and group dynamics during design projects. All-girl groups tend to make decisions collaboratively and prioritise safety, while all-boy groups tend to focus on scientific data, compete for leadership and take risks in their decision-making (Nam et al., 2020; Putra et al., 2023; Schnittka & Schnittka, 2016; Wieselmann et al., 2019a; Wieselmann et al., 2019b). Different gender compositions shape group dynamics and influence the way students think and participate during design tasks in both single- and mixed-gender groups. Understanding these patterns can identify and minimalise challenges, improve strategies and inform stakeholders on implementing those strategies in practice. Guzey & Jung (2020) highlight that looking at

gender and equal participation helps clarify to integrate engineering practices into K-12 STEM education.

Reflective decision-making (RDM) model

Batrouny (2022), Wendell et al. (2017) and Wright et al. (2018) provide possible strategies of decision-making during design tasks in small groups of elementary students through reflective decision-making (RDM). RDM by Wendell et al. (2017) is developed from empirical studies, built upon an iterative and evidence-based cycle, by examining how students plan, evaluate and improve solutions in complex design tasks. The RDM model is useful for this study since it is developed for the same age group. It can identify group decisions, communications and movements that include the redesign phase during the design tasks. This framework also makes design choices clear and easy to track (Wendell et al. 2017). This framework has been successfully implemented in K-12 during the design tasks by Batrouny (2022), Wendell et al. (2017) and Wright et al. (2018).

According to Wendell et al. (2017), RDM focuses on initial planning (the stage when students decide what they will build) and redesign (the stage where they build and improve their prototypes). Based on this, they identify six RDM elements in students' decision-making during EDP.

During planning phase, articulating multiple solutions (Element 1) involves students working in groups to identify and compare multiple possible solutions to a design challenge, deciding which ideas to consider. Evaluating pros and cons (Element 2) implies weighing the strengths and weaknesses of students' design choices, asking how likely each solution is to work. When intentionally selecting solutions (Element 3), students choose the option for the prototype they believe will most effectively solve the problem (Wendell et al., 2017).

Table 1 Reflective Decision-Making Evidenced During Redesign

Reflective decision-making action	What it looks like among urban elementary students	Decision to make
RDM Element 4: Retell performance of solution	Running commentary as test occurs	Did the prototype meet the design requirements?
	Pointing out flaws while referencing design sketch	
	Reminding team members of test results	
	Recasting negative test results as positive	
	Physically reenacting performance of a prototype	
RDM Element 5: Analyze solution according to specific evidence	Using critiques from other teams to make sense of design flaws	What made the prototype more or less successful?
	Interpreting test results as information about physical properties of materials	
	Describing test results from user's perspective	
	Proposing changes based on test results	
RDM 6: Purposefully choose improvements	Altering design sketch	What changes should we make?
	Proposing change of material	
	Justifying new materials selection by safety or usability	
	Demonstrating partially implemented improvement	
	Soliciting teammate cooperation in making physical changes	

Figure A. Table 1 RDM during redesign phase (Wendell et al., 2017)

In this study, the analysis focuses on the redesign phase, since the collected data from the planning phase was insufficient. Besides that, the redesign phase requires more intense work in groups settings. Figure A shows RDM elements during the redesign phase: Retelling performance of solutions (Element 4) directs students to reflect on how well their prototypes meet project requirements and whether it achieves the design goals. Analysing solution with specific evidence (Element 5) focuses on understanding why a prototype works well or fails by analysing its performance through different forms of evidence. Purposefully choosing improvements (Element 6) means students discuss and decide on specific changes to improve their designs during the redesign process (Wendell et al., 2017). This model allows for a detailed understanding of students' decision-making strategies.

Wendell et al. (2017) found that elementary students made reflective decision during engineering design. By considering their previous actions and feedback through initial planning and redesign, the groups discuss, analyse, and decide the next steps. Wright et al. (2018) specify that teams using RDM work well together to solve problems. Students can learn to critique ideas and offer constructive feedback, argue their perspectives using evidence and reasoning, and negotiate with teammates to reach solutions. Students can also create a "combining ideas" strategy in engineering classrooms to deal with challenges during group work. This strategy helps teams collaborate effectively, although it limits more in-depth engineering discussions, e.g. miss the chance to optimise critical analysis.

RDM during the design process can be challenging in collaborative settings. Sung and Kelley (2022) highlight that a big challenge in collaborative settings is associated with social skills: how to manage the flow (planning, directing, and coordinating) during the design process to understand the problems and choose solutions. Another challenge is different perspectives within a team, which depends on experience, task, complexity and contexts. McFadden and Roehrig (2018) mention the limitations of decision-making, such as confusion about the purpose of planning before building, group dynamics (e.g. communication styles and skills), everyday discourse practices, and lack of autonomous scaffolds. Additionally, students can face several obstacles to decision-making during design tasks: (1) "social competition", (2) "unnoticed failure" (e.g. students miss when their prototypes do not fully meet the design criteria and constraint), and (3) "technical and everyday vocabulary demands" (Wendell et al., 2017). Keeping these challenges and obstacles in mind, there are still advantages to groups' decision-making for engineering design tasks, such as (1) development of collaboration skills and critical thinking, (2) problem-solving skills, (3) collective choices, (4) equitable participation, (5) ideas iteration, etc. (Wendell et al., 2017). Jordan & Munguia (2015) noted that negotiating decisions in groups with multiple ideas can be seen as both challenging and

beneficial. Although different ideas might sometimes cause conflicts among the team members, working together improves their ideas and project. Wendell et al. (2017) also found that young students can think carefully about their choices during design tasks even if they do it in different ways. In this study, the RDM model can identify the gender group decisions in MYP1 class during the redesign phase.

Social Interdependence Theory (SIT) in co-design dynamics

Supporting the RDM model, Van Mechelen et al. (2014) acknowledge gender roles in mixed-gender group dynamics during the design task, although it is not a study on gender itself. The authors provide additional insight into how students (9-10-year-old) respond to each other in groups settings. Van Mechelen et al. (2014) analyse digital tools to improve groups collaboration and prevent (cyber)bullying. Students work in mixed-subgroups of four-to six children, seated together to strengthen their interdependence, combine diverse skills and ideas for effective collaboration. Their study shows that group dynamics (such as dominance, unequal participation, laughing out loud and conflict) might influence group collaboration and decision-making during design tasks. Van Mechelen et al. (2014) use the Social Interdependece Theory (SIT) as a framework to understand how people collaborate and compete. SIT has been often used in business and education, and the results have strong effectiveness and generalisability (Van Mechelen et al., 2014). The authors implement SIT's five mediating principles (positive interdependence, individual accountability, promotive interactions, appropriate use of social skills, and group processing) in co-design with children to deal with challenging group dynamics. The purpose of using SIT in this study is to identify gender group dynamics and collaboration styles that influence decision-making during design tasks. It adds nuance to identify those patterns since they are not covered by the RDM model. Although Schnittka and Schnittka (2016) explain that gender group dynamics exist within groups, they do not offer specific elements of these dynamics like SIT does. Gender roles influence how

individuals participate in group tasks with research showing that boys and girls often adopt different communication and collaboration styles, related to their decision-making (Van Mechelen et al., 2014).

To answer the research question, this study will implement design tasks by incorporating the marshmallow tower challenge (Zhou et al., 2017) into the school's curriculum design activity; designing a tower and building the prototype based on the design. The results of this study will provide better understanding and improve the effectiveness of how small groups engage during engineering activities, considering the role of gender. This study is mainly grounded in the RDM model by Wendell et al. (2017) to analyse students' decisions and engagement during the design process while looking at gender differences and group settings. In addition, this study incorporates Social Interdependence Theory (SIT), inspired by Van Mechelen et al. (2014) to show how group dynamics may influence the groups' decision-making, considering gender roles.

Methodology

This study used a qualitative research method, specifically a case study method. This method was chosen since it is suitable for analysing a phenomenon in its real-life context using multiple data collection methods. This research design is to ensure the study's reliability and validity that can improve its effectiveness (Priya, 2020). The aim was to examine how students (aged 11-12) in MYP 1 design class make decisions in groups during the design process, focusing on the role of gender.

This study integrated a hands-on task, the marshmallow tower challenge (Zhou, 2017) into the MYP1 design curriculum (see Appex. 1). The complete Marshmallow Tower challenge consisted of two parts: (1) a hands-on construction part, where students physically built the towers, and (2) a conceptual 3D design activity part, where students plan the design using

software to be 3D printed. However, due to limited time, the researcher only used hands-on design activities, focusing on students' collaboration, problem-solving and decision-making strategies during the redesign phase. The 3D design activity was implemented by the design teacher since it took more than two weeks according to the lesson plan.

Previous studies have focused on group composition and how group dynamics influence participation in decision-making and problem-solving during design tasks, comparing gender differences in single-gender and mixed-gender groups. This study is related to decision-making strategies and collaborations, focused on gender roles within single-gender-groups and was conducted in an MYP1A design class, taught by a design teacher. The researcher collected data from audio recordings of group participants and individual open-ended evaluation sheets. However, due to insufficient amount and poor quality of the audio recordings obtained during the initial planning phase, this paper reported only on the transcripts from the redesign/building phase and the students' evaluation responses. This limitation was acknowledged and future research should seek to collect more comprehensive data across all phases of the activity.

Participants

The participants were 25 students in MYP1A class, aged 11-12, at an international school in the Randstad area, the Netherlands. Recruitment of participants involved collaboration with a co-student who shared responsibility for contacting schools. We coordinated outreach efforts through email communication to ensure consistency and inclusion. The researcher selected international school students as participants because the school implemented International Baccalaureate (IB) programme, emphasising project-based learning (PBL). PBL equipped students with engineering principles, such as critical thinking, motivation, design decisions, argumentations and deeper understanding. PBL was also student-centred and encouraged them to explore real-world technical problems and see the connections

between science and engineering (Ejichukwu et al., 2024). These were also the goals of the IB MYP programme. Furthermore, the IB design class curriculum aligned with STEM activity and engineering design process (EDP) methods. This alignment ensured that learning experiences provided were related to the research objectives. All design activities took place in the design classroom and were scheduled for 1.5 hours once a week. This research took two days of design class.

The researcher sent a consent form to the design teacher about a month before the data collection. Then, the researcher provided detailed information, including a description of the roles of design teacher and researcher, as well as the consent forms. The design teacher was responsible for distributing the form to parents or guardians. Meanwhile, the design teacher and researcher exchanged detailed information, e.g. research plan, and the design teacher provided the lesson plan, materials and tools regarding the research project. After getting ethical approval and parental consent, 18 of 25 consent forms were signed and returned to the design teacher. The participants with consent consisted of 11 boys and 7 girls, and all their names were anonymised. The design teacher and researcher brainstormed how groups would be formed: talkative participants were mixed with less talkative ones to ensure sufficient data, and each group consisted of three to four members. Participants were assigned to either all-girl groups or all-boy groups to examine the research question of how decision-making strategies can involve younger students in the design process in small groups, considering the role of gender.

Instruments

All activities and discussions were recorded using a voice recording application on phones, and backup devices, e.g. a laptop and a tablet (Microsoft Teams audio recording). In addition to the main data sources, open-ended questions (“Marshmallow Tower Evaluation” sheet) were designed to provide more information about individuals’ thought process. Open-

ended questions can turn findings into interpretation (Rouder et al., 2021). These open-ended questions were developed by: (1) formulating the relevant questions to the decision-making during marshmallow tower task, e.g. specific, meaningful, interpretable; (2) formulating neutral questions but inviting; and (3) being concise to guide correct responses (Popping, 2015). This evaluation sheet was used as a data supplement. The researcher developed six modified open-ended questions in the evaluation sheet, including one with sub-items (see Appex.2), based on RDM model by Wendell et al. (2017) and *Decision-making worksheet* (n.d). The goal of this evaluation was to obtain students' reflection on the marshmallow tower challenge. The responses provided additional insights to support the validity of this study. Open-ended questions assessed students' understanding of design, prototyping, and collaboration (Zhou, 2017).

Data collection

The first day focused on initial planning of the marshmallow tower challenge. The researcher introduced the project, gave instructions and showed a tutorial video on drawing basic 3D shapes (e.g. cubes, prisms, pyramids, etc.). After watching the tutorial video, MYP1A students individually sketched their design ideas on graph paper.

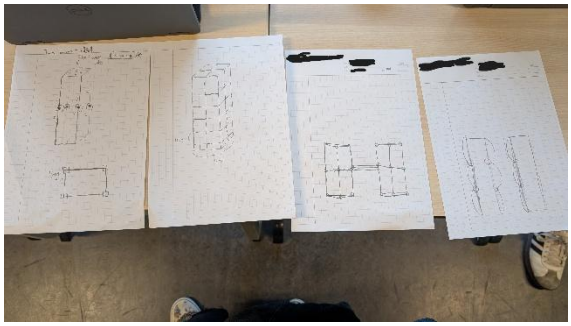

Fig 1. TwinTowers group (all-boy group)

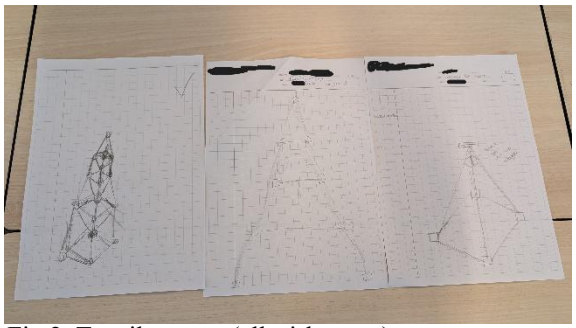

Fig 2. Tequila group (all-girl group)

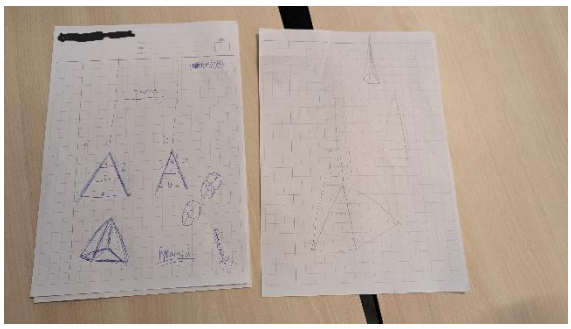

Fig 3. MarshmallowKings group (all-boy group)

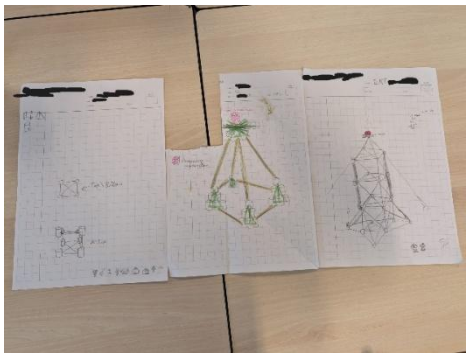

Fig 4. EAT group (all-girl group)

Figures 1 to 4 illustrate each participant's sketch of their own ideas before pitching and deciding which design to build. The sketching activity helped students visualise their ideas (Zhou, 2017). The design teacher helped the researcher assign students with consent into four groups (two boy-groups and two girl-groups). All-boy groups with consent consisted of four members each, while all-girl groups with consent consisted of three members each. To balance overall group composition, a boy and a girl with consent were added to single-gender groups that included students without consent. Each group selected a group name for easier anonymous identification. The four groups' discourse were recorded and fully transcribed during discussion, pitching and voting among the team members. The researcher used voice recording application on android phones. The researcher observed and noticed that some participants were aware of the recording and felt uncomfortable, at times remaining silent or even turning off the audio recorder.

The second day of design class was used for the redesign/building phase. The researcher introduced the activities and gave instructions for the second day, including refining their chosen design sketch, and redesigning phase: building the marshmallow towers. The conversations of the four groups were recorded. While the participants engaged in design activities, the researcher observed and listened to their discussions. Each group had to build the marshmallow tower based on the chosen design sketch. They could refine this within the first

15 minutes before starting the building activity. Next, each group received materials (16 kebab sticks, marshmallows, tape and toothpicks). However, one boy-group had to be disbanded due to limited materials, so the design teacher added two extra boys to each all-boy group. Thus, all-boy groups with consent consisted of five members each, while all-girl groups remained the same. Then, groups worked for 35 minutes to build the tallest free-standing tower.

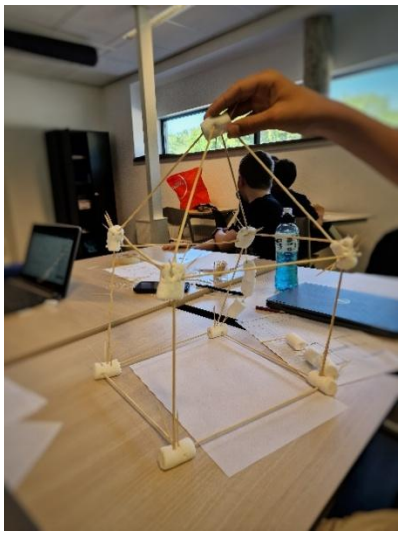

Fig 5. TwinTowers group prototype

Fig 6. Tequila group prototype

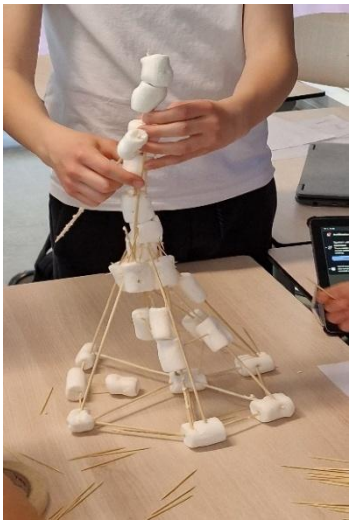

Fig 7. MarshmallowKings group prototype

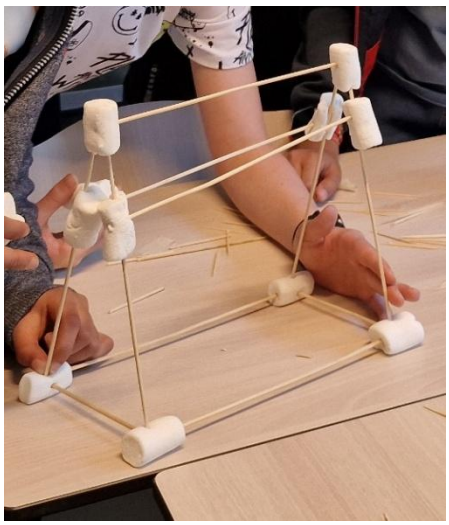

Fig 8. EAT group prototype

Figures 5 to 8 illustrate the prototypes from all single-gender groups in the marshmallow tower challenge, showing the results of their decisions and collaboration in

building the tallest free-standing towers. This hands-on activity taught basic engineering principle like tensions, compression, and the importance of a strong base while encouraging teamwork and problem-solving (Zhou, 2017). After building, all participants completed a marshmallow tower evaluation sheet with open-ended questions about their decision-making process during the tasks. The evaluation sheets of the 18 participants with consent were marked. However, two evaluation sheets from boys were incomplete. After that, each group could walk around and provide feedback to other groups about their prototypes.

Data analysis

A total of four groups participated with each group's conversation lasting approx. an hour, including a 15-minute class break; and the responses of the evaluation sheets from participants with consent were analysed using thematic analysis (TA). TA was chosen since it was flexible and suitable for exploring diverse qualitative data about individuals' experiences, views and social representations. It can be applied to various qualitative data types, from interviews to textual data (e.g. qualitative survey), and supports both data-driven (e.g. transcripts of audio recordings) and theory-driven approaches, across small and large datasets (Braun & Clarke, 2006). TA is a way to understand common patterns or themes in a data set, i.e. transcripts. It helps organise and describe the data in detail, but it can also provide deeper interpretation of the research topic (Braun & Clarke, 2006). Analysing the data happened in six stages, consisting of: (1) data familiarisation, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the report (Braun & Clarke, 2006).

In the first stage, the researcher listened to all audio recordings of group conversations and took informal notes, so that the researcher could capture initial impressions about what was interesting or relevant to the research question. All audio recordings were transcribed after the researcher listened to those recordings multiple times to distinguish the voice of each speaker,

identify lines of conversations and provide accuracy. This process helped the researcher become familiar with the data and informed the coding process, where patterns and themes were identified for the final analysis later on. Although transcription is time-consuming, it is an effective way to get familiar with the data. No single method is required to transcribe the recordings, but the transcript should be thorough, accurate and suited to the analysis (Braun & Clarke, 2006). The researcher used a locally installed audio editor application to reduce background noise, enhance voices and assist in voice to text conversion. Once the raw transcripts were ready, they were reviewed to ensure accuracy, so that researcher obtained a better understanding of the data. Then, the supervisor (second researcher) and the researcher discussed notes and developed some ideas for coding. Before applying the codes, the researcher re-read, made notes and broke down each transcript into episodes of group discourse. The irrelevant discourses were removed from the transcripts, such as school gossiping: *"Did she have a heart attack or something?"* (GirlA); gaming: *"It's a respawn anchor. So that's if you right click in..."* (BoyB); their lunch: *"The only thing I've eaten today was strawberries and mango"* (Boy1); music concert: *"Do you know that Billy Eillish was in Amsterdam"* (Girl1); etc. The remaining episodes in the transcripts were about the marshmallow tower challenge activity. The duration of each episode was determined by identifying thematic shifts and interaction patterns within group conversations. Transitions and episodes were marked by keywords e.g. "yeah", "no" or unfinished sentences which indicated a shift in topic. Periods of silence or pauses were also used to define start or end of episodes. Additionally, shifts from task-related discussions to off-task or gossip topics, followed by returns to on-task discussion, were considered indicators of episode changes. Sometimes their concentration lasted only a few seconds, while other times it could extend to 5 minutes per episode. This process created a database range between 58 and 90 episodes per group during the redesign phase.

In the second stage, the researcher applied the initial codes and assigned them as data in Atlas.ti. The researcher worked on the coding using existing codes from the redesign phase of RDM by Wendell et al. (2017) as a main framework. Additionally, the researcher added a few additional coding categories inspired by the SIT framework by Van Mechelen et al. (2014). Next, the researcher identified nuances in the data, and developed new codes to the existing frameworks. This aimed to enhance the analysis of how group dynamics influenced decision-making regarding gender differences. Sample and lines or keywords for all-boy and all-girl groups illustrated how the codes could be applied. Next, the supervisor and the researcher collaboratively compared, discussed and adjusted the codes into a codebook (see Appex. 3). In addition to the primary coded data, participants' responses in evaluation sheets (see Appex. 4) were coded and incorporated as supplement data to verify and support the primary data. Coding identified and categorised interesting and relevant parts of the data into groups, but the general themes were determined during the interpretation phase of thematic analysis (Braun & Clarke, 2006).

In the third stage, the researcher grouped codes with similar content or patterns into main and sub-themes that related to the research question. In the fourth stage, the supervisor and researcher checked and reviewed all data sets of each theme for consistency. In the fifth stage, the researcher described each theme in a few sentences and named each theme. In the final stage, the researcher reported the findings and provided samples from the data.

To make sure data analysis was reliable and accurate, the supervisor and researcher assessed the data with codes multiple times. After refining and developing the codebook, the researcher also invited the design teacher for a peer review to code a few episodes according to the developed codebook. Then, the supervisor and the researcher conducted a few formative inter-rater reliability (IRR) tests. IRR helped make qualitative study analysis transparent and

more consistent. It showed how codes and ideas were carefully made from the raw data (Cole, 2023).

An initial formative IRR test indicated moderate agreement, leading to refinement in the codebook and coder training. A second test showed high reliability, k=.672 ($p < .001$). This indicated significant agreement between the two coders, suggesting a reliable level of consistency in coding of the data. Assessing agreement in this way helps start meaningful discussions to get a deeper understand of the data (Cole, 2023).

Results

Results identified three main themes in decision-making strategies: 1) team cooperations & group dynamics, 2) project management during testing and improving, and 3) reflective decision-making; and various sub-themes for each theme regarding gender roles. These results illustrated how participants strategised and dealt with decision-making in group settings during redesign phase.

Theme 1: Team Cooperations & Group Dynamics

Both genders showed behavioural patterns within groups, including how team members collaborated, and resolved conflicts in decision-making during the redesign phase. The way they engaged with each other during the building activity provided insights into team cooperation and group dynamics.

1.1a All-boy groups highlighted charismatic authority

Twin Towers group showed that Boy1 led discussions, gave instructions or directed group activities by coordinating group members' actions. He also took charge of the group and strongly influenced the final decision-making process. Vignette 1 illustrated how Boy1 influenced their discussion and progress.

Vignette 1

Boy1: Put down, put down, put in the ground, put that on the floor

...

Boy4: Oh, I, I understand now... That's smart

Boy1: I'll play the first smart thing about me, huh? Nooo! Hey, hold this!

Boy4: Oh okay

...

Boy4: Where can I keep it more back?

Boy1: Wait

...

Boy4: "Oh wait, we're holding on..."

Boy3: "Here..."

Boy1: "Now what? No, no, no, no. Once it connects"

Other members just agreed with Boy1 in favour of maintaining team cooperation.

Vignette 2

Boy1: "Trust the process"

Boy2: "(name), I am,"

Boy3 "Trusting"

The written evaluation also reflected dominant behaviour of Boy1. *"Name of Boy1"* (Boy2_evaluationsheet) appeared when asked about the group's final decision-making on the marshmallow tower idea and decisions made during the task.

During the building activity, Boy1 led by giving commands such as *"Hey, hold this", "Wait"*. He ignored his teammates' feedback when they shared their thoughts on the prototype.

Vignette 3

Boy1: "Lift it up. What, what you need. You're not helping lift. Make sure it doesn't fall"

Boy4: "What? Are we making a house or twin towers? Leave it"

...

Boy1: “I ain’t leaving it”

Also, Boy5 expressed his willingness to contribute *“Give me something, then I’ll do anything”*, but he was ignored by other members.

Marshmallow Kings group also included a dominant member (BoyA). However, this dominance was expressed in a more indirect approach compared to Boy1 (Twin Towers group). For example, vignette 4 illustrated BoyA trying to take over the task, and insisted that his teammate follow his decision.

Vignette 4

BoyA: “Can I, can I, can I do this?”

BoyC: “Trust me”.

...

BoyA: “Listen, listen! I need to do this”

They tried to maintain equality in group decision during the task, as illustrated:

Vignette 5

BoyA: “Good job, wait, can I, can I?”

BoyC: “Sure. Yeah, put them”

However, BoyA still tended to act as a leader in the group *“Guys, guys, stop touching each other. You connect, you put it somewhere”* or *“Enough, shhsss”*, to refocus disengaged members back on the task. In this group, BoyE often showed a sense of superiority toward BoyD, *“Stay on your table.”* This reflected the group’s decision-making, as some members were often directing and the others followed or were corrected.

Despite the leadership style of BoyA, they still could work together and communicate well. The written evaluations also reflected their successful collaboration to the question what went well in the group, with responses like *“communication”* (BoyA_evaluationsheet), *“we worked and communicated very well”* (BoyB_evaluationsheet) and *“collaboration”* (BoyC_evaluationsheet).

These vignettes and sample lines illustrated that the authoritarian leadership and unequal participation in the Twin Towers group influenced the group process in decision-making by limiting input, discussion and participation; and regularly led to conflicts. These group dynamics also minimalised creativity and quality outcomes. In the Marshmallow Kings group, the leadership style may have helped them reach agreements faster, even though their analysis might not have delved deep into the issues. Still, they had better communication within the group.

1.1b All-girl groups emphasised support-driven

All-girl groups showed strong collaboration by sharing task responsibilities, verbal expression and supporting each other during the tasks. They also often looked for help, feedback or confirmation within the group.

Vignette 6

GirlA: "I'll actually, ah, ah, I'm holding this one, I'm holding this one"

GirlC: "Ready?"

GirlA: "Okay. 3, 2, 1, go!"

GirlB: "Yes!"

Another example:

Vignette 7

Girl3: "Can we talk?"

Girl1: "Yeah"

Girl2: "What bout my idea. Look!"

Girl1: "I have an idea with your idea"

Girl2: "Yea, let's do it. Tell me first"

This reflected that all-girl groups collaborated strongly, supported each other and help their team members during the task. The written evaluations also reflected their strong collaboration and contributions among the members *"We all contributed"* (Girl0_evaluationsheet),

"We did team work" (Girl2_evaluationsheet), "*We worked together well*" (GirlA_evaluationsheet), *"Our teamwork + collaboration"* (GirlB_evaluationsheet), *"We worked together and didn't argue"* (GirlC_evaluationsheet).

The support-driven patterns in all-girl groups enhanced team solidarity, provided diverse ideas in group settings. It also promoted equal participation, and open communication to solve problems.

1.2a All-boy groups engaged in personal clashes

All-boy groups demonstrated frequent conflicts during the group tasks. Although Boy1 dominated group decisions, some conflicts were caused by personal incompatibilities, and disagreement about what to do and how to do it. For example, *"That's not what we were gonna do that"* (Boy4); *"Okay, (name), what have you done to help? Huh, huh?"* (Boy1).

Marshmallow Kings group showed conflicts due to a language barrier and the challenge of a larger group size (5 members) in decision-making during the task.

> Vignette 8
>
> BoyA: No, no, no
>
> BoyE: "Waittt (screaming panicked), no, no, no
>
> BoyA: "Shhhsss,, shhhsss,, wait wait, wachten, wachten, daarop (in English: wait, wait for it). I got, I got this, shhss.. shhsss.. (name)
>
> BoyE: (Name)
>
> BoyD: "No, I wanna hold this"
>
> BoyE: "I wanna hold this?"
>
> BoyD: "I'm not doing it."
>
> BoyE mimicked BoyD's intonation and twisted his words: "You wanna hold piss?", BoyB acted as a mediator to stop the argument: "Hello," BoyE continued to taunt BoyD: "That's what he said. I wanna hold piss."

Vignette 8 illustrated that the process of soliciting teammates led to conflicts, and disagreements arose among the group members. The group's decision was made through a combination of strong statements made by BoyA, while BoyD and BoyE expressed their willingness to participate. However, BoyD ultimately withdrew since BoyE mocked his strong accent. During the group interaction, conflict also arose when BoyE started accusing BoyD,*"Why were you threatening that you would break this?"*, BoyD responded playfully, *"Ea, ea, ea?"*, ... Then, BoyA interrupted and asked BoyD for a clarity, *"What do you do..?"*. BoyE directly redemonstrated, *"When I came in with your pen, you were like, should I..."*, BoyC stepped into mediate, calling out *"(name), (name)"* to calm the group tension. However, BoyD switched to his mother tongue, *"... (unclear)"*, making his response unclear to the rest of the group. BoyE warned the others, *"Now he's gonna take something off"*, and BoyD showed his frustration, *"Take it"*. This discourse illustrated how switching to a different language at a crucial moment in the conflict limited their communications and resolutions, escalated misunderstanding and emotional responses among the group members regarding language differences.

The responses in the evaluation reflected their conflicts during the group tasks. Boy5_evaluationsheet mentioned "*Nothing*" what worked well in the group, *"Some of us disagreed with each other"* (BoyA_evaluationsheet); *"We kept going on, even though we ended with something we didn't want"* (Boy3_evaluationsheet); *"Some people didn't do anything"* (BoyC_evaluationsheet).

These conflicts impacted group reflection and decision-making process, creating tension during the task. These dynamics limited open communication and collaborative problem-solving. It might have contributed to poor decision-making and restrained their outcomes.

1.2b All-girl group highlighted constructive expression and tension

All-girl groups showed varying levels of tension during group tasks. Tequila group experienced conflicts more than EAT group due to disagreements and different opinions about their task approach. There also was tension due to stress during the task. Tequila group: *"What are you doing?"* (Girl3); *"I don't understand, was it that hard to make a normal block? Normal human block?"* (Girl1); *"I know we are the only two who's actually working"* (Girl2); EAT group: *"Stop, don't talk to me"* (GirlA).

Both all-girl groups showed disengagement, specifically due to failure in their prototypes and stress. Participants expressed negative feelings and frustration.*"If this falls, I'm gonna die today"* (Girl3); *"You know, I don't want to, I don't want to, I don't want to do this anymore"* (Girl2); *"No, this is bad, this is bad, this is bad"* (Girl1). The impact of stress was visible in the examples, *"This is too stressful for not to swear"* (Girl1). *"I'm so good at emotional support"* (GirlA); *"This feels completely wrong, I'll be completely honest"* (GirlB). The written evaluation also reflected negative feelings *"When we got mad"* (Girl3) as a main issue in Tequila group dynamics.

All-girl groups tended to engage in social loafing during the task. For example, GirlA described her role during the building activity as *"I'm doing marshmallow delivery"*. Another example illustrated that task focus sometimes shifted to playful moments splitting a marshmallow into two, half for eating and half for the project *"We're gonna be eating marshmallows that are split in a half, bro"* (Girl2).

These findings showed that stress caused emotional tension and disengagement during the task. It limited their attention and group decisions, as all-girl groups focused more on managing emotional responses than problem-solving.

Theme 2: Project management during testing and improving

All-boy and all-girl groups actively guided and tracked their process with team members. When receiving critical feedback during testing, all-boy groups tended to maintain positivity, by

staying confident about the results of their prototypes, and encouraging their teammates when receiving critical feedback from other groups during testing. However, their approach to building the prototype led them to explore design options at a surface level, and they provided less detailed explanations or refinements to their prototypes. On the other hand, all-girl groups focused more on details, coordination, and embodied engagement when providing critical feedback. These approaches highlighted differences in task-management by gender.

2.1a All-boy groups displayed multiple potential solutions concisely

All-boy groups were more likely to use concise, functional statements or phrases to track their progress during building activity. When they found out something happened with their prototype, they discussed efficient alternative strategies, focused on quick solutions instead of dissecting the issues. For example, *"Oh, it's a triangle, so twist"* (Boy1); *"I make it from all sides"* (Boy3); *"This is not gonna work"* (Boy4); *"It's falling"* (Boy5); *"That's quite high"* (BoyC).

However, when evaluating their work and analysing their prototypes, they also engaged in more reflective discussions. Aligning with Wendell et al. (2017), they also reminded their team members of what happened during previous tests for assessing potential solutions. For example, *"It was so good before, what happened?"* (Boy1); *"See, we made from 3 sticks, we made a long one"* (BoyE); *"...and the base because we worked a lot on that"* (BoyA); *"Yea our building, uh had a true, had a true 9-11"* (Boy1).

Despite their straightforward communication style, all-boy groups still provided critical feedback when acknowledging problems during testing. *"... the design is bad*" (Boy5), *"... it has no structure to it"* (Boy5); *"We don't have enough marshmallows on top"* (BoyC); *"There's no improving it"* (Boy1); *"No, no, it isn't stick in place"* (Boy1); *"I think this is not equal"* (BoyD). Several participants also described these issues in the evaluation sheet, such as *"The design, it's something that got messed up"* (Boy3_evaluationsheet); *"The way it looked overall"* (Boy4_evaluationsheet); *"Our only problem was the fact it was tilting"* (BoyB_evaluationsheet).

These examples from all-boy groups illustrated how their quick, task-related communications and critical feedback influenced their decision-making process. However, by focusing on quick solutions rather than analysing specific causes, the group might miss out on really digging into those issues. These reflected in both their discussions and evaluation sheets.

2.1b All-girl groups tended to be details-oriented

All-girl groups were more verbal during the group task. They provided extra information with more expression, keeping the group members in the loop while analysing and discussing outcomes. For instance, *"Why I'm trying to do an X?"* (Girl3); *"Oh, the middle is like okay"* (GirlA); *"Ta daa"* (GirlB); *"Guys, it's kind of leaning to this side"* (GirlC); *"Oh my God, it's standing"* (Girl2); *"Our nest is really.., oh my God"* (GirlA).

They also frequently reminded their team members of previous results to keep them on track. For example, *"Remember my idea with the cone?"* (Girl1); *"We used 31 marshmallows"* (GirlC); *"I told you it's too heavy"* (Girl2); *"I took off the top one, because this one the worst..."* (Girl1); *"That's why I split in a half"* (Girl2).

Additionally, all-girl groups acknowledged the problems extensively, offered critical feedback, and aimed to improve the groups' outcomes: *"A layer problem"* (Girl2), *"It's like weird sideways rectangle thingy"* (Girl2); *"These X-es aren't really staying"* (GirlC); *"This toothpick isn't long enough"* (GirlB); *"Here, why it's wrong bro!"* (Girl2); *"First of all, this is bending like that..."* (GirlC).

The sample lines illustrated that all-girl groups analysed problems of their prototypes extensively. They communicated openly, evaluated challenges together, and adjusted strategies as a team to find better solutions. They were expressive when sharing their thoughts or feedback to help their decisions and problem-solving.

2.2a All-boy groups tended to recast more negative experiences as positive

Although they used less frequent physical demonstrations, all-boy groups showed slight positivity towards failures and unexpected outcomes. For example, *"But at least I'm gonna make*

the failing of it look a bit sexier" (Boy1); *"It's not like it can be perfect. It's unique in its own way"* (Boy4); *"It'll actually look good"* (Boy3); *"I wasn't expecting this to work"* (BoyE); *"Listen, we tried our best"* (BoyA); *"...actually we're doing good"* (BoyA).

These sample lines illustrated that all-boy groups reflected on their outcomes with a resilient mindset, and their process of recasting negative experiences as positive outcomes to cope with challenges. This influenced how they made decisions together as a group, and helped them bounce back from failures.

2.2b Girls emphasised embodiment and improving efficiency

All-girl groups frequently used physical demonstrations during building, collaboratively sharing and refining their progress although the prototype was still incomplete or did not fully meet expectations. For example, *"You have to bounce it more that way..."* (Girl1); *"make these blocks like this"* (Girl1); *"I'm gonna grab this, and then put that right there"* (Girl2); *"I wanna move it"* (GirlC); *"Or just stick it like, right in the middle"* (GirlC); *"... and then put them also like around like this"* (GirlC). Participants also communicated their progress: *"I made another one"* (Girl2); *"I'm gonna do the support stuff..."* (GirlB); *"I'm doing the X's here"* (GirlB); *"I made the top one"* (Girl3); *"I added a last-minute support"* (GirlA); *"There, I fixed it"* (GirlB).

Several participants described their improvements in their evaluation sheet: *"We tried to fix it"* (Girl3_evaluationsheet), *"We added reinforcements by adding more toothpicks near the place where the problem was"* (GirlA_evaluationsheet); *"We added more toothpicks to make it more stable"* (GirlC_evaluationsheet).

Based on the data, all-girl groups engaged in group discussions and physical adjustments to the prototype. These behaviours reflected an iterative decision-making process. Throughout the task, they actively assessed and adjusted their prototypes by using gestures or body movements to clarify their points. This non-verbal feedback allowed them to demonstrate improvements. This embodied communication influenced their understanding and decision-making.

Theme 3: Reflective decision-making

3.1a All-boy groups focused on user's perspective

The data highlighted that all-boy groups tested materials and interpreted design results based on user's feedback and input. However, they showed less tendency to improve their prototypes by testing the materials. This displayed their focus on user's experience and usability by comparing their prototypes to an existing objects or real-life scenario. For example, *"He said twin towers of pizza"* (Boy1); *"Flip that and that looks like an ice cream cone"* (Boy1); *"It's abstract art"* (Boy2), *"Burj Khalifa"* (BoyB).

Moreover, they used feedback from other teams to understand their design flaws, such as *"He's aiming for the Twin Towers. Look at the house"* (Boy4); *"No... because it was the leaning twin towers of pizza"* (Boy1); *"No, but when you're saying ice cream cone"* (BoyA).

The findings illustrated that all-boy groups tended to be users and results-oriented. They were more likely exchange feedback with external groups instead of their own. The absence of altering design sketch might indicate that they preferred focusing on building rather than improving. Furthermore, all-boy groups were less likely to suggest improvements for their prototypes, and to justify or interpret materials used in their prototype.

3.1b All-girl groups demonstrated process- and alternative-oriented

All-girl groups displayed an iterative, data-driven approach to material selection and design. They frequently interpreted test results to inform their understanding of materials, and justify their material choices based on safety or usability. For example, *"Because the triangles are the strongest shape"* (Girl2); *"This toothpick isn't long enough"* (GirlC); *"Can you split the stick in half"* (Girl2); *"Why do these marshmallows look like bananas?"* (Girl2); *"Long kebab sticks"* (GirlC); *"...if it falls, it has the toothpicks that support"* (GirlA); *"Put it there, toothpicks...it's stable"* (Girl3).

They often suggested design modifications, including changing materials based on test results and were willing to refine and adapt their prototypes to meet their design goals. For

instance, *"Can we just do what we had as our first idea?"* (Girl2); *"I have to connect the marshmallows and then do the X"* (GirlA); *"I have a bigger idea, ... why don't we just make a triangle base? ... A mini triangle base to make it just high off?"* (Girl2); *"Hey guys, I have another idea. We're gonna make it smaller"* (Girl1); *"...take 10 back to 4" (Girl3); "We can just put skewers instead of placing marshmallows"* (Girl2); *"We changed because it wouldn't stand up"* (Girl2).

Several participants in all-girl groups suggested the improvements to meet their design goals, *"Make it taller"* (Girl0_evaluationsheet); *"We would add more stability to the tower or make it taller"* (GirlA_evaluationsheet); *"More stability + height"* (GirlB_evaluationsheet); *"I would make it with more details" (Girl1_evaluationsheet)*.

The findings illustrated that all-girl groups showed a process- and visual oriented approach. They planned carefully and paid attention to visual details throughout their work. They showed strong technical analysing skills, and responded effectively when issues arose with their prototypes. Moreover, they frequently suggested multiple improvements and alternative solutions, reflecting their problem-solving skills. Additionally, all-girl groups tended to optimise the materials during building. However, they might prefer having feedback primarily from their own team members rather than relying on external groups.

These results above showed that MYP1A students made decisions during the redesign phase by soliciting teammates for help, managing and improving their projects during testing, and reflecting on their decisions. The quality data analysis was primarily performed using the RDM model (Wendell et al., 2017), considering gender roles. The results also revealed additional findings indicating that all-boy groups sometimes demonstrated dominant and charismatic leadership, faced a language barrier, and experienced conflicts. In contrast, all-girl groups showed supportive but constructive expressions, along with tensions during group decisions. While these additional findings were not the primary focus of this study, they were still valuable to be considered as the data was extensive. All findings will be discussed in light of the literature in the following section.

Discussion

The aim of this study was to investigate how secondary school students make decisions in small groups during the redesign phase of the design task, considering gender roles. Since the planning phase data was insufficient, the researcher focused on the redesign phase where participants engaged in more intensive group work and dealt with more challenges. It required more collaborative skills, hands-on problem-solving, and group decisions. The findings in this study provided insights into decision-making strategies, primarily through the lens of the reflective decision-making (RDM) model (Wendell et al., 2017), and highlighted ways these strategies can enhance the engagement of younger students in the design process.

Team cooperation and group dynamics reveal behavioural patterns that influence groups' decision-making, impacting collaboration and conflict resolution. These findings indicate different group dynamics and cooperation styles between all-boy and all-girl groups during the redesign phase. All-boy groups exhibited authoritarian leadership styles, such as Boy1 and BoyA who tended to lead discussion and dominate decision-making. They often impose their ideas rather than asking input from others, which limit participation from quieter group members. These behaviours often escalate into conflicts, and reduce collaboration and group cohesion. This authoritarian leadership can constrain the exchange of ideas, reduce opportunities for mutual reasoning and the quality of the outcomes. These findings align with Wieselmann et al. (2019b), who emphasise that boys often competed for dominance and leadership during planning, selecting materials and design stages of the design task. The authors highlighted that this can limit participation and disrupt group collaboration. Also, self-oriented speech from BoyA (e.g. "Can I, can I do this?") reflects individual control over team work, viewing the design task as a competition or personal project rather than a collaboration (Wieselmann et al., 2019b). Similarly, Wendell et al. (2017) identify social competition as a barrier to RDM during design tasks. This competition (for both academic and social status) can

limit collaboration skills, and make it difficult to merge ideas from multiple members. This study extends these findings by illustrating how such group dynamics (dominance, unequal participation, and conflict) may influence collaboration and decision-making process of all-boy groups during design tasks. This echoes Van Mechelen et al. (2014) who found that dominance leads to rushed decisions without considering other options (groupthink), and conflicts reduce serious engagement with the task (laughing out loud) or escalate disagreements that divide the group. These patterns highlight how easily teamwork can become unstable when collaboration and reflection are not supported. Members in all-boy groups are apart together which means they work alone and only put the results together on a surface level (Van Mechelen et al., 2014). These patterns can be addressed by group processing, where students take time to think about how they are working together and decide what they should do or change (Van Mechelen et al. 2014).

In contrast, all-girl groups worked together through support-driven cooperation, enhancing team solidarity, sharing diverse ideas, participating equally and communicating openly to solve problems. These results align with findings from Nam et al. (2020); Schnittka & Schnittka (2016); Putra et al. (2023); Wieselmann et al. (2019a, 2019b) where members of all-girl groups take on supporting roles, engage in collaborative discussions, have equal participation, maintain solidarity, and prioritise group harmony. These behaviours reflect students' discourse and epistemological beliefs, shaping girls to emphasise more cooperation and emotional connection than boys (Nam et al., 2020). Socio-cultural norms and values can encourage girls to focus on teamwork, harmony and avoid conflict (Schnittka & Schnittka, 2016). Putra et al. (2023) also note that girls tend to focus on planning and discussing collaboratively, but they engage less in design tasks, as women are expected to show soft attitudes in Javanese social culture. In this interaction style, girls tend to focus on sharing and supporting each other rather than on competing or leading tasks (Wieselmann et al., 2019a).

These findings indicate that all-girl groups tend to be supportive, which is shaped by social learning and a preference for group harmony.

Conflicts and tension also played significant roles in decision-making in both gender groups. The findings in all-boy groups revealed that conflicts were caused by personal clashes, a language barrier and a larger group size. Van Mechelen et al. (2014) note that dysfunctional conflicts during co-design may occur from personal issues or disagreements about what to do (task conflict) and how to do it (process conflict). This can lead to defensiveness and failure in teamwork. Similarly, Nam et al. (2020) highlight that all-boy groups frequently show challenging interaction, where ideas are criticised in ways that increase disagreement or conflict instead of encouraging negotiation. These behaviours explain why all-boy groups in this study struggle to manage the challenges of teamwork and decision-making. Wendell et al. (2017) emphasise students' technical and everyday vocabulary demands as a limitation of RDM, which may exclude participants less familiar with the vocabulary. In that case, students often struggle to express their thoughts clearly during group discussions. Their unclear language makes it harder for teammates to fully understand each other's ideas and reach a shared meaning (Wendell et al., 2017). The issue of a language barrier in one of the all-boy groups impacts their decisions and collaboration.

In all-girl groups, emotional tensions and disengagements were often triggered by stress or frustration. This shifted their attention from focusing on the task to managing their emotional responses. These findings also relate to Wieselmann et al. (2019a; 2019b) who found that girls expressed frustration with the task and their peers when they felt that their ideas were ignored or progress was slow. Frustration can increase when some teammates contribute less and work inefficiently. Girls can also become frustrated and quit when the material presented is challenging (Putra et al., 2023). These reactions impact their motivation and communication styles (Wieselmann et al., 2019b). These behaviours suggest that all-girl groups may need

additional support in managing their frustrations and tensions by sharing tasks and rotating group roles (Wieselmann et al., 2019a). To deal with these problems, Van Mechelen et al. (2014) offer two types of interventions: (1) roles strategies: negotiation, clarifying tasks and giving role-specific activities to help students understand and embrace their responsibilities; and (2) resources strategies: guiding them to find solutions without giving extra materials, resulting in improvement of collaboration and task distribution (Van Mechelen et al., 2014).

Project management during testing and improving reveals evident gender differences in how groups manage and track their task. Results indicate that all-boy groups tend to prioritise quick solutions over in-depth analysis which influences their decision-making process. For example, all-boy groups consider potential challenges quickly without discussing details or dissecting the issues when they discovered problems with their prototypes during building. The speed in the discussion appears to limit the groups' ability to thoroughly analyse problems and explore solutions. This finding echoes Schnittka & Schnittka (2016) that all-boy groups may value the final results over equal participation. This indicates that all-boy groups often prioritise performance and result orientation over collaboration and reflection.

In contrast, all-girl groups focus on extensive analysis, open communication, group reflection as an iterative process, and expressive feedback on their prototypes. These processes help to refine group understanding and guide problem-solving. It aligns with Wieselmann et al. (2019a), indicating metacognition as a sign of learning in design, where students intentionally plan, monitor and reflect on their learning process. In their study, only all-girl groups engaged in an unprompted discussion about their most difficult decisions and their reasons. They also split tasks equally, reviewed input from their peers and developed ideas collaboratively (Wieselmann et al., 2019a). These behaviours are evidence of a stronger orientation toward reflective practice, deeper understanding and engagement throughout the design process. (Wieselmann et al., 2019a).

A resilient mindset and reframing negative experiences as positive outcomes are found in all-boy groups to cope with challenges. This reflects Wendell et al. (2017) who highlight an "epistemological framing approach". This is a shift from negative to positive mindset, especially when solving problems. Also, it can shape how students learn from those experiences. Also, boys' performance is generally being viewed as more competent in using persistence and deep learning strategies to deal with design challenges (Putra et al., 2023). All-girl groups use embodied communication (hand or body gestures) to clarify their points and improve their prototypes. Design thinking related to embodied cognition suggests bodily interactions are a key part of thinking, as the body can shape, share or guide the cognitive process (Zhou et al., 2019). For example, students use gestures, and visual representations to physically engage with their prototype (e.g. handling materials or sketching ideas), to help them generate new ideas and solve problems (Zhou et al., 2019). Wieselmann et al. (2019b) also found that girls handled materials more frequent than boys.

Reflective decision-making appears as an overarching theme that shapes how teams work together, manage projects and refine their ideas. It demonstrates how groups make decisions by considering their goals, solving problems and reviewing their progress to address design challenges. Findings indicate that all-boy groups were user-and-results-oriented. They focus on completing prototypes rather than improving or analysing them, which reflects a mindset that prioritise finishing over improving. They also tended to seek external validation or feedback from other groups to justify their prototypes. This echoes Schnittka & Schnittka (2016) who emphasise a lack of group cohesion when boys see the design process as a competition since they confirm their ideas by comparing them with other groups. Boys are likely to use more challenging and defending language in social negotiation patterns (Nam et al., 2020). These relate to social competition identified by Wendell et al. (2017).

In contrast, all-girl groups show an iterative mindset by visualising, analysing, alternating and improving their prototypes. The discussions about improvements, material optimisation and alternative solutions, indicate a deeper engagement with the design process. Both gender groups apply the design thinking process in this case, but all-girl groups seem to engage more reflectively by reconsidering earlier decisions and using feedback to refine their prototypes. Design thinking can develop students' innovation in problem-solving (Carroll et al., 2010). In addition, all-girl groups tend to prefer getting feedback from their own team members to solve problems. This mirrors that they support and assist their own teammates (Nam et al., 2020; Schnittka & Schnittka, 2016; Wieselmann et al., 2019a, 2019b).

This study suggests gender influences final decision-making of secondary school students during design tasks viewed through the lens of the RDM model. Results build on previous studies on gender differences in engineering design among secondary school students. Differences in leadership, communication, reflection, and task orientation align with existing literature, highlighting the importance of promoting inclusive and supportive groups to enhance reflective decision-making and the design process among secondary school students. All-boy groups often show social competition (Wendell et al., 2017), and self-oriented speech (Wieselmann et al., 2019b), which contributes to authoritarian leadership. In contrast, all-girl groups tend to emphasise inclusivity, collaboration, solidarity, and group harmony. These patterns reflect female socio-cultural norms and values, communication, and interaction styles (Nam e al., 2020; Schnittka & Schnittka, 2016; Wieselmann et al., 2019b). These group dynamics shape how boys and girls approach problem-solving and decision-making differently, which can be seen in their task-orientation and reflection. All-boy groups tend to prioritise final results over equal participation (Schnittka & Schnittka, 2016), and reframe negative experiences as positive outcomes as a strategy to shape their performance (Putra et al., 2023; Wendell et al., 2017). In contrast, all-girl groups show metacognitive awareness (Wieselmann

et al., 2019b), and demonstrate embodied cognition (Zhou et al., 2019). All-girl groups demonstrate an iterative and cognitive process. A similarity between both genders is the use of evidence to support their reasoning during the redesign phase.

Previous studies have emphasised the importance of the teacher's role in facilitating small groups and using STEM teamwork protocols (Schnittka & Schnittka, 2016; Wieselmann et al., 2019a, 2019b). Those studies recommend teachers to form small groups of two to four, assign and rotate group roles (e.g. materials manager, design leader, or data collector), and facilitate solutions for conflicts and negative emotions (Schnittka & Schnittka, 2016; Wieselmann et al., 2019a).

The limitations of this study include unequal group sizes between all-boy groups (5 each) and all-girl groups (3 each). Extra participants in all-boy groups may have influenced their decision-making process during the task. It was out of the researcher's control due to constraints related to limited materials. Furthermore, the evaluation sheet questions could be improved, as some responses were irrelevant to the questions asked. This suggests that the questions may not have been optimal for obtaining focused answers. The data collection period was also limited, possibly influencing the depth of the collected data. This study only relied on audio recordings for data collection, which limited the ability to capture the non-verbal cues (e.g. gestures). Although the researcher observed participants' engagement with their prototypes, the precise nature of their gestures could not be fully documented. It may have led to a general interpretation of embodied communications.

Conclusion and Recommendations

In conclusion, this study found that the RDM model (Wendell et al., 2017) can facilitate secondary school students to reflect on group decisions during redesign phase. The findings reveal gender differences in leadership, communication styles, inclusivity, reasoning,

reflections, and supportive and task-oriented behaviours. These differences influence their decision-making process and strategies in groups.

These insights offer practical implications for educators regarding STEM group activities. For team composition, teachers can form mixed-gender groups to enhance collaboration. Single-gender groups can be formed as a safe-environment when students might be uncomfortable working with other genders in a group. These group compositions depend on the class sizes and/or cultural background of the students. Teachers can assign group roles to team members which should be rotated so that each student can experience different roles. Providing students with clear guidelines and instructions on how to engage and manage emotions helps them work better in groups. Teachers can maintain positive interdependence by implementing self-regulation strategies, such as goal setting, environmental structuring, task strategies, help seeking, self-evaluation, and time management (Huang & Lajoie, 2023). This way individuals see the need to work together to reach a shared goal (Van Mechelen et al., 2014). Teacher can prepare students with cognitive appraisal training in groups before the design task. Cognitive appraisal can help individuals interpret situations that influence their well-being when emotions arise (Yeo & Ong, 2024). These interventions can support effective emotion regulation strategies, train students to work in groups, and support social-emotional skills, regardless of group size. This can also keep everyone equally involved and minimalise the downsides of authoritarian leadership, group tension and conflicts. Huang & Lajoie (2023) suggest encouraging positive social-emotional interactions through Socially Shared Regulation of Learning (SSRL), where students plan, carry out tasks, reflect and adapt together as a group. This practical instruction and intervention can reduce conflicts, enhance collaboration, and teamwork. It can also promote the strengths of both gender groups in design projects.

This study suggests that future research should explore how communication styles and embodied cognition influence the design process along with SSRL and the teacher's role.

Understanding these relationships can clarify how RDM and collaborative dynamics develop and how they influence task-orientation and engagement in design activities. It is recommended to use equal group sizes, and implement the think-aloud method along with video recording to collect richer data. Extending the duration of data collection to both planning and redesign phase can be beneficial.

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Appendices

Appendix 1: Marshmallow tower challenge and lesson plan

The marshmallow tower challenge was adapted from Zhou (2017). Students worked in small groups using 16 kebab sticks, marshmallows, tape and toothpicks to build the tallest free-standing structure. This 35-minutes activity encouraged collaboration, problem-solving skills and hands-on learning about engineering principles such as tension, compression and the importance of a strong base for stability, followed by group discussions in design thinking in the curriculum.

Lesson plan - Day1

Criterion A (inquiry – product analysis) & Criterion B (sketching ideas)

- Brief introduction and outline the role of researcher in the project
- Students will share their research on building structures as part of inquiry phase of the project in their initial teams
- Each student will create individual design sketches based on simple line drawings (maximum 16 lines)
- Presentations include analysis of different building structures, the 2D and 3D shapes they use and materials
- Students will present their ideas to each other and vote on the design idea they want to build

Lesson plan – Day2

Criterion B (Ideation), C (Creating the solution), D (Evaluation: quick verbal feedback)

- Students will improve their drawings and build their marshmallow towers (e.g. houses, towers, bridges, etc.)
- Students will provide quick verbal feedback on the prototype built by other groups

Appendix 2: Marshmallow challenge evaluation (modified open-ended questions)

Marshmallow Challenge Evaluation

Group name: .....

1a. What were the different marshmallow tower ideas during sketching?

.....

1b. How did you come up with these different ideas?

.....

1c. How did your group decide on a final marshmallow tower idea to build?

.....

1d. What other things did you consider in making this decision?

.....

2. When you had problems with your design/tower, did you stop working? What did you do?

.....

3. How did you decide on the changes to make?

.....

4. If you had more time, what would you change or make better in your design?

.....

5. Please describe what worked well in your student group?

.....

6. What did not work so well in your student group?

.....

Appendix 3: Codebook

1

Reflective decision-making (RDM) action	What it looks like among MYP1A students	Descriptions	Samples - Boys	Samples - Girls
RDM Element 4: Retell performance of solution	4.01 Running commentary as test occurs (Wendell et al., 2017)	Students talk out loud during building activity to say what is happening (action/performance of prototype), neutral and positive	"That's quite big", "Have a look", "They all be marshmallow like that", "Oh, it's a triangle, so twist", "Wait, let it fall, let it fall", "Whoa, this is actually working", "It won't work", "It looks bad", "Look, it's keeping the structure", "It fell on the ground", "Look, look, it's a perfect base", "… see what happen", "We need like two marshmallows", "It's gonna fall", "I make it from all side", "Such accuracy"	"Ta..daa", "Done! Beautiful", "Guys, this will not work", "Oh my God, it's standing", "It's kind of like it fell", "I don't think that's gonna stand", "Fine, Look, I wanna see", "It's working guys", "Look, standing!", "This is not good", "…that's good", "…it's failed", "It's too high", "It's about tumble over", "It's straight now", "Guys, it's kind of leaning to this side", "The X is broken", "It's falling this way", "It should hold if we just stop now", "We have enough", "mine is moving", "That's better", "the middle is like okay", "It's too big"

2

Reflective decision-making (RDM) action	What it looks like among MYP1A students	Descriptions	Samples - Boys	Samples - Girls
	4.02 Pointing out flaws while referencing design prototype or sketch (Wendell et al., 2017)	Students mostly show teammates which part are not working by referring to the prototype, only a few referring to sketch, negative	"I don't get it. That's way too big", "The design is bad", "…It has no structure to it", "I miss the line", "But we don't have enough marshmallow on top", "It isn't stick in place", "We only have one more marshmallow", "…it doesn't look very stable", "Everything is twisted", "I think this is not equal", "It's not very sturdy", "There is no improving it", "Do you know, it's supposed to be twin towers", "…. look at this, our structure, our building", "…there's not gonna be enough", "What's the thing at the bottom?"	"A layer problem", "…is this wonky? Looks like a rhombus", "It's like weird sideways rectangle thingy", "This is not stable with this", "This is too much this way", "…It's gonna make it weak otherwise", "These X-es aren't really staying", "Guys, the marshmallow is starting to break", "This toothpick isn't long enough", "Here, why it's wrong bro!", "It's missing, we need to use…", "First of all, this is bending like that…", "There's no supports on this one"

Reflective decision-making (RDM) action	What it looks like among MYP1A students	Descriptions	Samples - Boys	Samples - Girls
	4.03 Reminding team members of test results (Wendell et al., 2017)	Students remind each other of what happened during earlier tests. It comes from the past test-results. Students sometimes make comparisons to previous results/parts (past tense)	"It was so good before, what happened?", "We already made that", "Because it kind of like fell apart", "…it was kind of broken", "It would, we just needed to get us some support", "Exactly! This is how it's done", "See, we made from 3 sticks, we made a long one", So that way they can't move. See, that one can't move", "Yea our building, uh had a true, had a true 9-11", "…we wanted it to be like a kind of pyramid, but that quickly just disintegrated…", "…the base because we worked a lot on that…", "We're not done yet"	"What the hell happened?", "I told you it's too heavy", "That's why I split in a half", "Remember my idea with the cone?", "I took off the top one, because this one was the worst…", "You said it was gonna work", "We did it", "I think we might have used one here", "Yeah, this is the moldy one. One of our ideas", "We used 31 marshmallows", "We haven't done at all", "What did you do?... Someone put a marshmallow there", "We broke our marshmallow", "Who the hell did that?", "We don't have toothpicks. That's the problem", "We took a whole bowl", "I did… mine is stuck there"

Reflective decision-making (RDM) action	What it looks like among MYP1A students	Descriptions	Samples - Boys	Samples - Girls
	4.04 Recasting negative test results as positive (Wendell et al., 2017	Students try to stay positive *after* (see previous lines) disappointing results, sometimes social or on tasks	"This actually kind of looks good if you twist it", "But at least I'm gonna make the failing of it look a bit sexier", "It's not like it can be perfect. It's unique in its own way", "It'll actually look good", "…This isn't that bad", "Something like this is already fine", "It's better than nothing", "I wasn't expecting this to work", "Yea, it's like a core, it's much better", "Listen, we tried our best", "It's okay", "Don't worry", "…actually we're doing good"	"…The same size as ours. Bro, then ours is fine too", "We're getting somewhere. Look at this", "It will be fine, don't worry", "…to get it. We have something better", "I don't think we're gonna win with height, but we might win stability", "Guys, this is so good", "I can't believe this is actually standing", "It's fine, it's the best we can do right now", "…it's more support, that's perfect. We're doing it, guys"
	4.05 Physically enacting performance of a prototype (Wendell et al., (2017)	Students use their gestures/body movements how the prototype perform to make their points clearer (think twice if there's a movement)	"like this?" "add", "connect", "stick it", "keep on stacking them", "put", "If you do it backwards, it can",	"stab", "take off", "add", "Shall I drop it down?", "Like this, like that", "put", "Keep it slow", "You have to bounce it more that way...",

Reflective decision-making (RDM) action	What it looks like among MYP1A students	Descriptions	Samples - Boys	Samples - Girls
			"…it can't twist like this, it will like, you use the toothpicks to support the engine", "Try this", "Look, look. Now do this", "This stick should be going right here", "I'm gonna take this up", "Guys want me to spin?", "… we connect 4 sticks to it…", "…now do this", "We have to move this here", "It can go like this"	"I pulled it", "A little bit lower", "here", "…make this, one of the sticks stick to other sticks", "I'm just gonna open it up", "Y'all attaching it", "make these blocks like this", "I'm gonna grab this, and then put that right there", "we keep them straight", "I wanna move it", "I push…", "Weave it in", "Or just stick it like, right in the middle", "…and then put them also like around like this", "Try to put that…", "…not in here", "…another one there…"
RDM Element 5: Analyze solution according to specific evidence	5.01 Using critiques from (other) team(s) to make sense of design flaws (Wendell et al., 2017)	Students use feedback from students on other teams to understand design flaws	"He's aiming for the Twin Towers. Look at the house", "No…because it was the leaning twin towers of pizza", "You have to create a cube",	"GirlA: Do you think your marshmallow can stand? Girl2: Yea, it's gonna like stay"

Reflective decision-making (RDM) action	What it looks like among MYP1A students	Descriptions	Samples - Boys	Samples - Girls
			"No, but when you're saying ice cream cone that like"	
	5.02 Interpreting test results as information about physical properties of materials (Wendell et al., 2017)	Students interpret test results (see previous lines) to judge whether the materials they choose are appropriate	"The size does matter", "So squishy", I was thinking half of sticks", "They look so thick", "big stick", "There's too many marshmallows", "…Like with a bigger stick", "It needs more marshmallows powers", "…I stuck these two together. Extra super glue", "small stick", "We need one more big stick…"	"Because the triangles are the strongest shape", "Put in half", "The marshmallows are so sticky", "sticky", "moldy", "lumpy marshmallow", "mini marshmallow", "so squishy", "It has glue though", "We have a lot here", "Split the stick in half", "this toothpick isn't long enough", "long kebab sticks", "big sticks", "I'm literally feeling the 2 different ones", "So, that the marshmallow has like three things", "Too thick…", "this one is green", "Maybe they liked dried up or something",

Reflective decision-making (RDM) action	What it looks like among MYP1A students	Descriptions	Samples - Boys	Samples - Girls
				"Why do these marshmallows look like bananas?", "We have a lot here", "Yea, this is big", "The toothpicks are little too short", "…this one feels softer than these ones…", "…this marshmallow, this is gonna be like the balancing, the balancing marshmallows"
	5.03 Describing test results from user's perspective (Wendell et al., 2017)	Students consider what it would be like for someone using their design, comparing to an existing object, real-life scenario	"He said twin towers of pizza", "Flip that and that looks like an ice cream cone", "it's abstract art", "Burj Khalifa", "It has to be a structure"	"Because the triangles are the strongest shape", "... look this is diagonal", "safety hazard", "What if it has to go through an earthquake?"
	5.04 Proposing changes based on test results (Wendell et al., 2017)	Students suggest specific changes to fix the prototype	"can", "could", "should", "want last stick at the top", "We can make ...", "I want to show you", "I think we should put this ...", "I shouldn't make our own Twin Towers",	"Can we just do what we had as our first idea?", "We're gonna have to restart the whole thing",

Reflective decision-making (RDM) action	What it looks like among MYP1A students	Descriptions	Samples - Boys	Samples - Girls
			"I'm just gonna copy them. I'll get it in. I gotta dismantle everything, okay?", "Make a tower like them…", "…are you up making a square? It means that we only do one building", "Maybe if you put one diagonally", "I want last stick at the top", "I want stick it. I guess we have to support the base in order to go up", "We need structure like that", "Guys maybe if you put one or two marshmallows, that would look good"	"I have to connect the marshmallows and then do the X", "We need to make the nest", "I'll fix it" "should", "can", "…maybe we need that middle thing", "I have an idea ... split it in half", "I have a bigger idea, ... why don't we just make a triangle base?... A mini triangle base to make it just high off", "Can I just try something?", "What about my idea, look!", "Wait, I have a plan", "Let's make it even more taller, see that", "I think we should do it like this", "Well, I know how to make…", "We have a change of plan… we can put…", "How about if this is gonna work? Put it on top",

Reflective decision-making (RDM) action	What it looks like among MYP1A students	Descriptions	Samples - Boys	Samples - Girls
				"Hey guys I have another idea. We're gonna make it smaller", "I think you should go up"
RDM Element 6: Purposefully choose improvements	6.01 Altering design sketch (Wendell et al., 2017)	Students modify a design sketch	N/A	"We could've found a different design", "... I have different design in my head", "We changed because it wouldn't stand up"
	6.02 Proposing change of material (Wendell et al., 2017)	Students suggest new materials they believe would better meet their design goals	"This is like extra", "I was thinking half of sticks", "Can you ask the teacher for one?"	"Can we have more of the longer kebab sticks?", "…take 10 back to 4", "Someone has scissors?", "We can just put skewers, instead of placing marshmallows", "Instead of marshmallows we use tape for everything", "We can start with the kebab", "I need another mini marshmallow", "We need a face scoop", "…this is better, because they're bigger…"

Reflective decision-making (RDM) action	What it looks like among MYP1A students	Descriptions	Samples - Boys	Samples - Girls
	6.03 Justifying new materials selection by safety or usability (Wendell et al., 2017)	Students choose materials based on how safe or easy to use	"use", "Maybe you wanna use another stick to hold it against…", "See, it has to be marshmallow itself', "Guys, we don't need stick…", "We just need marshmallows and toothpicks", "I need tape, "We need one more big stick, one more", "You guys use toothpicks for support"	"use", "And then we can use the toothpicks here", "Take that much off the marshmallow. You can make it longer", "Give me a stick for stableness, for extra stableness", "We need small toothpicks", "We need 4 marshmallows for the bottom", "Put it there, toothpicks…it's stable", "…You have the scissors", "…if its falls, it has the toothpicks that support", "I think we should save it in case for emergency"
	6.04 Demonstrating partially implemented improvement (Wendell et al., 2017)	Students show each other whether a partial improvement work or not (see previous lines)	"show", "fix", "do", "I'm gonna try to show you what I was doing", "First like this ...", "First, do like the, the base ...", "Trust me, trust me. Like this, like this", "I'm just doing the bridges, cause they help for stability…",	"fix", "do", "make", "That's fixed", "I made another one", "I took off the top one, because this ...", "I'm gonna do the support stuffs…", "I'm doing the exes here", "I made the top one",

Reflective decision-making (RDM) action	What it looks like among MYP1A students	Descriptions	Samples - Boys	Samples - Girls
			"…also since we did it very symmetrical", "…Ok, now that we created it", "I think one in the middle and on the top is ok"	"Let me try to do something", "Put this to make this steadier", "Look. Mold it, or..", "Guys, I found something stable I made", "Guys, the marshmallow on top works", "I added a last-minute support", "I'm doing something", "…we have something to make it like this side more…", "I'm adding toothpicks…at the bottom of these, in case, they ever fall, the toothpicks are gonna save them", "I can fix it", "There, I fixed it"
	6.05 Soliciting teammate cooperation (Wendell et al., 2017)/Collaboration styles	Students collaborate to make the changes to the prototype. Students show collaboration styles, i.e. sometimes a dominant or charismatic student influences the group, while others work	"Let's start", "Hold", "Wait", "Try this", "Let's go", "Trust the process", "Trust me", "That's what I said", "Hey, that's just too far", "Let's stop", "Enough, shush", "I never want to move here", "I'm	"hold", "hold this", "help", "Put a marshmallow in there", "Wait, wait, wait, put another stick there. I'll hold it", "Gimme", "Help me", "Let's do it ...", "What do you think I've been saying",

Reflective decision-making (RDM) action	What it looks like among MYP1A students	Descriptions	Samples - Boys	Samples - Girls
		separately and only combine results later. Success depends on each student's contribution. They need to balance working with friends and collaborating with others by listening, supporting and helping each other to reach shared goals. Additionally, they seek confirmation from their teammates.	in your group", "Good luck", "But it's ok, it's ok", "Good job", "Why are you in our group?", "Where can I keep it more back?", "No, listen!", "No, just let me", "Are we making a house or twin towers? Leave it!", "Guys, chunk on them", "Hey, shut up!", "There are too many people", "Can I do this?" "do you have sticks?", "Look, look. Stop, stop, stop. Yeah?", "Can you please help us?"	"Oh my God, guys, stop!", "Guys, uhm", "Be careful", "This feels so satisfying", "What are these kebab sticks?", "Why are we making that already a triangle?", "Should I put here?", "Don't drop it!", "Look just trust me, take this apart okay?", "You know that can work, right?", "That's what I'm saying", "You do it, I'm busy", "Shall we?", "Wait. Should we do the top right now or later?", "Can I please do something?", "Wait, I have an idea", "Can you like fix this later?", "Grab", "How do we make this work?", "We're using all our 3 brain cells combine…", "…Can you break it?", "Put them on", "I told you…", "Go!", "We have like 30 seconds", "Oh

Reflective decision-making (RDM) action	What it looks like among MYP1A students	Descriptions	Samples - Boys	Samples - Girls
				yeah, we need small toothpicks", "Pointy part goes up, guys", "Do you think our tower is gonna stand up?", "I get it, I get it", "We can't abandon our tower, guys", "Wait for me"
7. Additional Codes	7.01 Personal Clashes	Students got into conflicts due to personal incompatibilities and disagreements within their groups about what and how to do it	"That's not what we were gonna do that", "What are you doing here?", "What have you done to help?", "I'm gonna keep hating on this", "Why you threaten to break this?", "B4: This is summative, mate. B3: this is not a summative. The things that are after is. B4: We want to reflect on something that we did well, we haven't really done well. B1: No, no, no	"How did we copy you?", "You guys don't even know what to do", "What are you doing?", "Guys, you won't get a good grade for this", "You idiot. This is our plan. Are you dumb?", "Did you do that? Take it apart", "Stop. Take that off", "Go away", "I don't understand, was it that hard to make a normal block? Normal human

Reflective decision-making (RDM) action	What it looks like among MYP1A students	Descriptions	Samples - Boys	Samples - Girls
			but genuinely, it's it's much easier to do reflection something that you've done horrible", "They copied us", "There's no way we're taking this apart", "I didn't do anything. I had mouth off", "I'm not giving you anything…",	block?", "What the hell did you say?", "I know we are the only two who's actually working", "Are you absolutely blind?", "Stop. Don't talk to me"
	7.02 Disengagement behaviour and attitudes	Students engage in social loafing and laugh out loud during the task. They also experience negative feelings while working on it	"You know what's impossible? For you to stop yapping about seagull", "What the hell are you doing? Why are you on me?", "No…, why's there one in the middle?", "Leave me alone", "game", "giggling", "I want to, but I watch an episode", "You're playing games", "I want to eat marshmallow", "Yea, I'm breaking it", "I'm	"I don't like this anymore. I thought this is gonna be fun", "I'm tired", "I don't like this", "I feel so bad", "I don't care", This feels so wrong", "Marshmallow delivery", "I wanted to sneak a bite right now", "Look at my new weapon", "... to eat", "giggling", "If this falls, I'm gonna die today", "I don't want to do this anymore", "This is so bad", "How was yummy", "This is too stressful for

Reflective decision-making (RDM) action	What it looks like among MYP1A students	Descriptions	Samples - Boys	Samples - Girls
			mentally helping people", "You look very sad, because we thought we're not worth", "It's a house for the wind blow", group members sing, "I'm gonna keep hating on this", "Is that a spider?", "Swallowing it", "laugh", "bully-bait", "It's a house for the wind blow"	us not to swear", "I'm scared", "Say it to the phone…we wanna play castle…", "I'm spuder-man", "laughing", "This is so hard", "I'm gonna keep practicing with chopsticks", "I'm good at emotional support", "singing"

Appendix 4: Evaluation sheets – participant responses

Marshmallow Challenge Evaluation

Group name: The Special Ed Children – Boy0

1a. What were the different marshmallow tower ideas during sketching?

Firstly, we thought that every layer we would put one stick connecting the layer, but after time, we thought of the best solution

1b. How did you come up with these different ideas?

We all drew separate buildings and after voting we chose mine the Burj Khalifa.

1c. How did your group decide on a final marshmallow tower idea to build?

Well, we just started 2D and then slowly we added dimensions

1d. What other things did you consider in making this decision?

We considered making it mostly sticks and a few marshmallows but chose otherwise

2. When you had problems with your design/tower, did you stop working? What did you do?

No, we had problems with stability but we made more

3. How did you decide on the changes to make?

We voted

4. If you had more time, what would you change or make better in your design?

Stability

5. Please describe what worked well in your student group?

Everything

6. What did not work so well in your student group?

N/A

Marshmallow Challenge Evaluation

Group name: Twin Towers – Boy1

1a. What were the different marshmallow tower ideas during sketching?

There were all other similar ideas were one the stick limit

1b. How did you come up with these different ideas?

(drawing himself)

1c. How did your group decide on a final marshmallow tower idea to build?

As it was the only one that had structural support that fit the stick range

1d. What other things did you consider in making this decision?

Stick amount

2. When you had problems with your design/tower, did you stop working? What did you do?

We voted together

3. How did you decide on the changes to make?

With a vote

4. If you had more time, what would you change or make better in your design?

Yes

5. Please describe what worked well in your student group?

Me

6. What did not work so well in your student group?

(name of Boy5) → Boy1 changed the Q, "who did not work so well in your student group"

Marshmallow Challenge Evaluation

Group name: Twin Towers – Boy2

1a. What were the different marshmallow tower ideas during sketching?

Twin Towers

1b. How did you come up with these different ideas?

Name of Boy1

1c. How did your group decide on a final marshmallow tower idea to build?

Name of Boy1

1d. What other things did you consider in making this decision?

Bridge

2. When you had problems with your design/tower, did you stop working? What did you do?

Name of Boy1

3. How did you decide on the changes to make?

Name of Boy1

4. If you had more time, what would you change or make better in your design?

No

5. Please describe what worked well in your student group?

Name of Boy1

6. What did not work so well in your student group?

Name of Boy1

Marshmallow Challenge Evaluation

Group name: Twin Towers – Boy3

1a. What were the different marshmallow tower ideas during sketching?

One with using 16 sticks to make two towers & one with using all 16 sticks to make one towers

1b. How did you come up with these different ideas?

We all have a different thinking process and that's only we all had different ideas

1c. How did your group decide on a final marshmallow tower idea to build?

Where we can use 16 sticks to make 2 towers

1d. What other things did you consider in making this decision?

To help each other and try making it look good

2. When you had problems with your design/tower, did you stop working? What did you do?

We kept going on, even though we ended with something we didn't want

3. How did you decide on the changes to make?

It happened according to the situation/conditions

4. If you had more time, what would you change or make better in your design?

Definitely, why not. It's always better to....

5. Please describe what worked well in your student group?

Probably the handling the situation when our tower was about to fall

6. What did not work so well in your student group?

The design, it's something that got messed up

Marshmallow Challenge Evaluation

Group name: Twin Towers – Boy4

1a. What were the different marshmallow tower ideas during sketching?

To make it stable

1b. How did you come up with these different ideas?

While collaborating and talking together

1c. How did your group decide on a final marshmallow tower idea to build?

By thinking what would work the best

1d. What other things did you consider in making this decision?

How big the base will be

2. When you had problems with your design/tower, did you stop working? What did you do?

We stopped to think but that's it

3. How did you decide on the changes to make?

What the structure will look like

4. If you had more time, what would you change or make better in your design?

To keep it stable

5. Please describe what worked well in your student group?

Collaboration went well

6. What did not work so well in your student group?

The way it looked over all

Marshmallow Challenge Evaluation

Group name: Twin Towers – Boy5

1a. What were the different marshmallow tower ideas during sketching?

I came in the group later, so I don't know

1b. How did you come up with these different ideas?

I came into the group later so I don't know

1c. How did your group decide on a final marshmallow tower idea to build?

It has no structure and very BAD!

1d. What other things did you consider in making this decision?

I came in the group later so I don't know

2. When you had problems with your design/tower, did you stop working? What did you do?

Yes, we had problems but my group stopped working on it, but I wanna work on it. It was falling

3. How did you decide on the changes to make?

I came in to the group later so I don't know

4. If you had more time, what would you change or make better in your design?

Yes, add more structure

5. Please describe what worked well in your student group?

Nothing

6. What did not work so well in your student group?

Everything

Marshmallow Challenge Evaluation

Group name: The Marshmallow Kings - BoyA

1a. What were the different marshmallow tower ideas during sketching?

First we wanted to make an idea like the twin towers but we changed our minds

1b. How did you come up with these different ideas?

We did by brainstorming together

1c. How did your group decide on a final marshmallow tower idea to build?

We decided by voting

1d. What other things did you consider in making this decision?

The pyramids inspired us

2. When you had problems with your design/tower, did you stop working? What did you do?

We had to created stronger base

3. How did you decide on the changes to make?

By talking

4. If you had more time, what would you change or make better in your design?

I would make it tidier

5. Please describe what worked well in your student group?

Communication

6. What did not work so well in your student group?

Some of us disagreed with each other

Marshmallow Challenge Evaluation

Group name: The Marshmallow Kings - BoyB

1a. What were the different marshmallow tower ideas during sketching?

There were 2 main ideas, mine and BoyA. Mine was based on the twin towers, we used BoyA's ideas

1b. How did you come up with these different ideas?

I thought of a simple building that had great stability. The twin towers came to mind. I thought of only doing one

1c. How did your group decide on a final marshmallow tower idea to build?

We remembered that triangles are the strongest shape and BoyA consisted of a triangles

1d. What other things did you consider in making this decision?

I considered kind of joining our ideas, but I realised they were very different

2. When you had problems with your design/tower, did you stop working? What did you do?

Our only problem was the fact it was tilling but we added stability

3. How did you decide on the changes to make?

We didn't have many changes

4. If you had more time, what would you change or make better in your design?

Maybe make it more straight

5. Please describe what worked well in your student group?

We worked and communicated very well

6. What did not work so well in your student group?

Nothing

Marshmallow Challenge Evaluation

Group name: The Marshmallow Kings - BoyC

1a. What were the different marshmallow tower ideas during sketching?

We tried to make pyramids and then we did the Eiffel tower

1b. How did you come up with these different ideas?

We wanted to use triangles so we did the 2 structures

1c. How did your group decide on a final marshmallow tower idea to build?

We wanted to do a tall structure

1d. What other things did you consider in making this decision?

We wanted to do a very tall design

2. When you had problems with your design/tower, did you stop working? What did you do?

We did not have any problems

3. How did you decide on the changes to make?

We did not change anything

4. If you had more time, what would you change or make better in your design?

We would make it bigger

5. Please describe what worked well in your student group?

The collaboration

6. What did not work so well in your student group?

Some people didn't do anything

Marshmallow Challenge Evaluation

Group name: Quad Squad – Girl0

1a. What were the different marshmallow tower ideas during sketching?

A triangle and two pyramids

1b. How did you come up with these different ideas?

For me from a series and the other I don't know

1c. How did your group decide on a final marshmallow tower idea to build?

Because we had enough materials

1d. What other things did you consider in making this decision?

How big it will be, do we have enough time and materials

2. When you had problems with your design/tower, did you stop working? What did you do?

We kept building

3. How did you decide on the changes to make?

We decided because we wanted to make it taller

4. If you had more time, what would you change or make better in your design?

Make it taller

5. Please describe what worked well in your student group?

We all contributed

6. What did not work so well in your student group?

We like eating marshmallows

Marshmallow Challenge Evaluation

Group name: Tequila – Girl1

1a. What were the different marshmallow tower ideas during sketching?

Mainly based on triangles and tall standing structures

1b. How did you come up with these different ideas?

We just drew what came to mind

1c. How did your group decide on a final marshmallow tower idea to build?

We just did somehow

1d. What other things did you consider in making this decision?

Shapes, height and structure

2. When you had problems with your design/tower, did you stop working? What did you do?

We re-started

3. How did you decide on the changes to make?

We did what we thought of

4. If you had more time, what would you change or make better in your design?

I would make it with more detain

5. Please describe what worked well in your student group?

Different ideas

6. What did not work so well in your student group?

When we got mad

Marshmallow Challenge Evaluation

Group name: Tequila – Girl2

1a. What were the different marshmallow tower ideas during sketching?

We thought that to make an Eiffel tower, etc.

1b. How did you come up with these different ideas?

We randomly chose these different ideas

1c. How did your group decide on a final marshmallow tower idea to build?

We thought to pick the best one from all so yea

1d. What other things did you consider in making this decision?

Shapes, height and structure

2. When you had problems with your design/tower, did you stop working? What did you do?

We shared up in internet

3. How did you decide on the changes to make?

We just did what we thought of

4. If you had more time, what would you change or make better in your design?

I would make the design more better

5. Please describe what worked well in your student group?

Coming up with different ideas

6. What did not work so well in your student group?

We did team work

Marshmallow Challenge Evaluation

Group name: Tequila – Girl3

1a. What were the different marshmallow tower ideas during sketching?

Many about triangles and squares

1b. How did you come up with these different ideas?

I honestly do not know

1c. How did your group decide on a final marshmallow tower idea to build?

We decided on this one because it looked stable

1d. What other things did you consider in making this decision?

Shapes, height

2. When you had problems with your design/tower, did you stop working? What did you do?

We tried to fix it

3. How did you decide on the changes to make?

We did what we thought was good

4. If you had more time, what would you change or make better in your design?

The whole design

5. Please describe what worked well in your student group?

Coming up with different ideas

6. What did not work so well in your student group?

When we got mad

Marshmallow Challenge Evaluation

Group name: EAT - GirlA

1a. What were the different marshmallow tower ideas during sketching?

One idea was a triangle, another was a cube, so we combined them to get this towers

1b. How did you come up with these different ideas?

We all thought separately then talked about our ideas

1c. How did your group decide on a final marshmallow tower idea to build?

We combined all of our ideas to make this perfect tower

1d. What other things did you consider in making this decision?

We considered to make a pyramid of marshmallows, but didn't add them, because it wasted too many marshmallows

2. When you had problems with your design/tower, did you stop working? What did you do?

We added reinforcements by adding more toothpicks near the place where the problem was

3. How did you decide on the changes to make?

We all thought about it as a group and tried to imagine in our heads how it would look like

4. If you had more time, what would you change or make better in your design?

We would add more stability to the tower or make it taller

5. Please describe what worked well in your student group?

We worked together well

6. What did not work so well in your student group?

We didn't have many ideas

Marshmallow Challenge Evaluation

Group name: EAT - GirlB

1a. What were the different marshmallow tower ideas during sketching?

We started with just triangles then squares then we combined everything

1b. How did you come up with these different ideas?

We thought separate then shared

1c. How did your group decide on a final marshmallow tower idea to build?

We mixed our ideas together to make it better in structure

1d. What other things did you consider in making this decision?

We considered adding marshmallow pyramids, but didn't in the end

2. When you had problems with your design/tower, did you stop working? What did you do?

We added support and reinforcement in weak areas

3. How did you decide on the changes to make?

As a team we imagined what it would look like

4. If you had more time, what would you change or make better in your design?

More stability + height

5. Please describe what worked well in your student group?

Our teamwork + collaboration

6. What did not work so well in your student group?

Not a lot of ideas

Marshmallow Challenge Evaluation

Group name: EAT - GirlC

1a. What were the different marshmallow tower ideas during sketching?

One of our ideas was to make a triangle, another was to make cubes, and our final idea was to put a triangle on top of cubes

1b. How did you come up with these different ideas?

We all thought of our ideas separately and then we shared them

1c. How did your group decide on a final marshmallow tower idea to build?

We mixed our ideas together so everyone's would be used and no one would feel left out

1d. What other things did you consider in making this decision?

We considered adding marshmallow pyramids, but we decided not to because it would take too many marshmallows

2. When you had problems with your design/tower, did you stop working? What did you do?

We added more toothpicks to make it more stable

3. How did you decide on the changes to make?

We thought about it as a group, and imagined what it would look like in our heads

4. If you had more time, what would you change or make better in your design?

More stability and taller

5. Please describe what worked well in your student group?

We worked together and didn't argue

6. What did not work so well in your student group?

We didn't have many ideas