Exploring the Relation between Self-Efficacy and Uncertainty in the Realm of Collaborative Learning Tasks

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Abstract

This study explores the relationship between self-efficacy, uncertainty, and reported self-competency among students engaging with digital engineering tasks. This study delves into the impact of uncertainty on students' perceived competence, aligning with Dewey's emphasis on uncertainty as a catalyst for learning and Csikszentmihalyi's flow theory linking uncertainty to creative problem-solving. Employing a mixed-methods approach, an experiment was conducted at the DesignLAB, University of Twente.

The results revealed a significant negative effect of uncertainty on self-competency, highlighting the influence of varying uncertainty levels on students' perceived competence while engaging in engineer design tasks. Furthermore, a negative association between self-efficacy and reported self-competency was found, emphasizing the need for ongoing measurements to capture the dynamic nature of these constructs.

Despite limitations in participant pool size and audiovisual data quality, this study contributes valuable insights for educators and policymakers. Recommendations for future research include implementing repeated measures for self-efficacy assessment, increasing sample size, and enhancing recording conditions. By addressing these challenges, a more rounded dataset can be ensured, strengthening the validity and interpretability of findings.

Keywords: engineering tasks, self-efficacy, uncertainty, self-competency, collaborative learning

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Uncertainty is an integral aspect of human cognition, influencing individuals' subjective experiences, cognitive feelings, and decision-making processes (Schwarz and Clore, 2007). In collaborative learning activities, uncertainty has a significant impact on learning and social interaction dynamics (Jordan et al., 2012). Piaget (1972) stated that learning is often the outcome of a dynamic process, in which generating uncertainty causes a restructuring of existing beliefs, values, and conceptions. Uncertainty may be purposely increased in certain educational situations, such as design projects and creative problem-solving, to encourage innovation and long-term learning (Glanville, 2007).

Uncertainty

To understand the significance of uncertainty, it is important first to understand its position in education. As defined by Jordan and McDaniel (2014) uncertainty is an individual's subjective experience of doubts about how the future will unfold, what the present means, or how to interpret the past.

Dewey (1934) proposed that when one is facing uncertainty and unfamiliar situations, they are more motivated to think critically and come up with creative solutions. He emphasised the importance of uncertainty as a catalyst for learning. In makerspaces, students often meet new and hard challenges, sparking their curiosity and problem-solving abilities, thus aligning with Dewey's ideas. Similarly, Csikszentmihalyi (1996) proposes in his flow theory that uncertainty, when balanced with the individual's possession of the necessary skills, allows for the individual to get into a state of flow in which they are more likely to experience moments of creative problem solving and engagement.

Types of uncertainty

Information-seeking uncertainty is a prevalent form that involves individuals actively seeking information to feel less uncertain. These individuals are motivated to gain clarity about the future, the present, or the past (Afifi & Afifi, 2009).

Another common strategy is ignorance or maintaining uncertainty. In some situations, individuals intentionally ignore or maintain uncertainty, recognising that reducing it is not always a desirable or feasible goal. This choice may come from considerations such as overarching goals (Babrow & Mathias, 2009).

Sometimes an individual keeps their uncertainty intentionally. Things like creative problem-solving and innovation sometimes necessitate intentionally generating uncertainty to stimulate the exploration of new ideas. Collaborative brainstorming, for instance, may involve intentionally keeping uncertainty to help new idea creation before resolving the uncertainty (Mueller, Melwani, & Goncalo, 2012; Tiedens & Linton, 2001).

Self-efficacy

Self-efficacy, a key concept in psychology rooted in Albert Bandura's Social Cognitive Theory from 1977, plays a leading role in the field of education. According to this theory, self-efficacy revolves around an individual's belief in their ability to effectively act, overcome obstacles, and achieve desired results.

According to Schwartz and Jerusalem (1995), self-efficacy expresses a person's general confidence in their ability to manage a wide range of situations. Next, Bandura (1982) suggests that people who have high levels of self-efficacy typically approach activities with optimism and see obstacles as chances for improvement and mastery. This tendency translates into more perseverance, dedication, and effort in their academic achievements.

In addition, people who have higher levels of self-efficacy also prove more resilient in the face of adversity (Bandura, 1993). Failures are viewed as important teaching moments that spur on later attempts rather than as impassable obstacles. These people are more likely to see setbacks as instructive lessons learned than as proof of their shortcomings. The influence of self-efficacy beliefs extends beyond behaviour to cognitive processes. Individuals with high self-efficacy can vividly envision successful scenarios, enhancing their problem-solving and planning abilities (Bandura, 1986). This mental rehearsal influences their self-regulation and goal-attainment strategies, facilitating effective navigation of complex academic tasks.

Additionally, self-efficacy affects how decisions are made in educational settings. Zimmerman (2000) theorised that individuals with high levels of self-efficacy are more likely to actively seek out chances for intellectual growth, hold themselves to high academic standards, and embrace challenges in the classroom.

Emotional resilience and the affective components of self-efficacy are significantly correlated (Bandura, 1993). Strong self-efficacy increases a person's resilience to stress, as well as their capacity to control their emotional reactions in tough learning environments. Compared to those with lower levels of self-efficacy, who are more likely to experience anxiety and self-doubt, they can manage challenging academic situations better (Bandura, 1997). Furthermore, positive affect and emotional well-being are promoted by high self-

efficacy (Caprara et al., 2003). Strong self-efficacy beliefs lead to a greater sense of achievement, less stress, and greater academic pleasure for the individual. Their general psychological health is strengthened by this emotional well-being, which also improves the quality of their educational experiences.

Current Study

The current study aims to explore the relationship between self-efficacy, uncertainty and reported self-competency in the context of digital engineering activities. By studying the dynamics of uncertainty in engineering design problems, this study aims to gain a better understanding of how students engage in collaborative problem-solving in the field of engineering. To address this, the following research question was formulated:

How does self-efficacy influence the effect of uncertain environmental situations on reported self-competency?

To answer this research question the following four hypotheses were formulated:

Hypothesis 1: Uncertainty has a significant negative effect on self-competency

Hypothesis 2: Self-efficacy has a significant positive effect on self-competency

Hypothesis 3: There is a correlation between uncertainty and self-efficacy

Hypothesis 4: Self-efficacy significantly moderates the effect between uncertainty and self-competency

Methods

Research Design

To investigate whether self-efficacy has an influence on self-reported competency, an experimental study was conducted. A mixed-method research design was employed to explore the relationship between self-efficacy, uncertainty and reported self-competency in makerspaces. A mixed-method approach was used, as both qualitative and quantitative data were collected to give a better understanding of the research problem. The qualitative component involved collecting open-ended surveys, analysing speech and behaviour, and interviewing the participants after the experiment with open-ended questions. The quantitative component, on the other hand, utilized established scales to measure self-efficacy, self-regulation, and self-competency. The experimental setup, conducted at the DesignLAB at the University of Twente, involved participants engaging in a digital engineering task.

The research team consisted of three female students, two Psychology bachelors, and one Educational psychology master's student. The study was submitted to the BMS committee with request number 231283 and was approved.

Participants

An initial sample of 15 individuals was obtained through convenience sampling, two of whom were unable to attend due to illness, reducing the final sample size to 13. The study included individuals aged 18 to 30 who were mostly affiliated with the University of Twente or Saxion Hogeschool Enschede. Furthermore, the participants were split into four groups based on their familiarity with each other. Participants who did not, or barely knew, each other were put together. Lastly, the participants were not granted any rewards for participating, there were some food and drinks available during the experiment, however.

Materials

Instruments

To gain insight into the participants' base self-efficacy the General Self-Efficacy Scale (GSE) was used, developed by Schwarzer, R., and Jerusalem, M. (1995) (See Appendix A). This scale was created to assess a general sense of perceived self-efficacy to predict coping with daily hassles as well as adaptation after experiencing all kinds of stressful life events (Schwarzer & Jerusalem, 1995b). The overall reliability, in samples from 23 nations, had a Cronbach's alpha that ranged from .75 to .90. The survey uses a 4-point Likert scale. Going from "Not at all true" to "Exactly true". Example questions from the General Self-Efficacy Scale are:

"I can always manage to solve difficult problems if I try hard enough".

"Thanks to my resourcefulness, I know how to manage unforeseen situations"

"When I am confronted with a problem, I can usually find several solutions"

In addition, the AIRE instrument, designed to measure self-regulation was used (Järvenoja et al., 2013) consisting of a combination of closed and open-ended questions to collect both quantitative and qualitative data (See Appendix B). It assesses individual and social factors influencing regulation processes during collaborative learning activities, providing insight into students' subjective experiences within groups. Their survey consisted of three sections. All answers could be given in 4-point and 5-point Likert scales, depending on the section. Example questions are:

"Make sure my grade is not going to be low because of the group"

"Get new ideas from the group''

"Our goals for the project were different"

Additionally, the SSRL-charts (Socially Shared Regulation of Learning) were used (See Appendix C) This instrument can indicate the perceived self-competency of the participants separately and the group (Panadero & Järvelä, 2015).

As a final questionnaire, four open-ended questions were asked to better assess uncertainty within the participants with the following questions:

"What are you not sure about?"
"What are you wondering about?"
"What are you confused about?"
"What are you anxious/frustrated about?"

To assess the level of uncertainty in the participants, pre-defined markers were used that stated what type of uncertainty the individual expressed (Jordan et al., 2014; See Appendix D).

Additional materials

For the experiment, various instruments were used. The software used in the task was Energy3D, a digital simulation-based engineering tool for designing eco-friendly buildings (See Appendix E). The participants were provided with tips about solar energy and sustainability (see Appendix F).

Each table was prepared with a bundle of papers, pencils, a laptop running the Energy3D software, a touchscreen, and an energy-saving and insulating information brochure. Food and beverages were also provided throughout the experiment. Near each table, one of the 360° Kandao cameras was mounted to record video and audio of the respective group.

Procedure

At the beginning of the experiment, the participants were divided into groups of three or four at the onset of the experiment, with tables pre-set up by the researchers. They were then asked to complete the informed consent forms (see Appendix G). Participants were then given a code (A1, A2, A3, etc.) to use on all subsequent documents to anonymize their data. After everyone had read and signed the documents, they had a few minutes to go over and discuss the task instructions given to them as a group. Before beginning the activity,

participants completed the self-efficacy measure and the first section of the regulation survey, which focused on individual ideas (See Appendix A and B). After finishing the questionnaire, the participants began the first exercise.

In this round, the groups were prompted to collaborate on a design for a net-zero energy house using the Energy3D simulation program, following specific criteria. They had about 25 minutes to complete the trial. Afterwards, they individually filled out SSRL radar charts and answered four uncertainty questions on a blank sheet, discussing these results afterwards within their groups.

After a 10-minute break, the second round followed. Here, the challenge was to create another net-zero energy house, but this time, groups had to use the original base. They could not change the base's shape or size but had to stick to the same budget of €200,000 within a time limit of 20-25 minutes. After finishing, participants again filled out SSRL radar charts and answered the four uncertainty questions on a new sheet (See Appendix C).

After another 10-minute break, the final round began. This time the groups were tasked with improving their previously built house, fixing mistakes, and ensuring it met net-zero energy criteria, all within a 10-minute window. After completion, each group filled out the last set of questionnaires, including SSRL radar charts, the four uncertainty questions, and the second part of the regulation survey (see Appendix B), thus wrapping up the data collection phase.

Data analysis

The data was collected and then analysed in R-studio (version 2023.12.0+269; See Appendix H). This analysis is aimed to explore the correlation between self-efficacy and uncertainty management for students doing digital engineering tasks. To answer this specific research question, only the general self-efficacy scale and the SSRL charts were used. The videos and audio recordings were coded but deemed not useful.

Direct Effect of Uncertainty on Self-Competency

To explore the direct effect of uncertainty on self-competency, a linear regression analysis was performed. The linear regression was chosen to examine the direct impact of uncertainty on self-competency, as this model gives an understanding of the relationship between two continuous variables and assesses the strength and nature of their association. Self-competency is the dependent variable (DV), and Uncertainty is the independent variable (IV). The level of uncertainty was categorized per round, the most uncertain being 3 and the least uncertain being 1.

Effect of self-efficacy on self-competency

The relationship between self-efficacy and self-competency was explored using a linear regression analysis. This model is suitable for assessing the influence of an IV on a DV. The dependent variable is self-competency and self-efficacy is the independent variable. Using this, it could be determined how variations in self-efficacy influence perceived self-competency.

Correlation between uncertainty and self-efficacy

To determine and understand the bivariate relationship between uncertainty and self-efficacy, a correlation coefficient was measured. This measure allowed us to assess the strength and direction of the correlation, indicating how the two variables interacted.

Moderation analysis

To explore the moderating effect of self-efficacy on the relationship between uncertainty and self-competency, a moderation analysis was conducted.

Results

Descriptive Statistics

Descriptive statistics provide a brief overview of descriptive coefficients that summarize the dataset. Participants, on average, reported a mean self-competency score of 2.927, with a minimum of 1.833 and a maximum of 4.000. Self-efficacy scores had a mean of 2.908, ranging from 2.600 to 3.200**,** indicating variability in participants' confidence in their ability to accomplish tasks within the given context.

The levels of uncertainty ranged from 1 to 3**,** the qualitative analysis involved the identification of coded text indicating expressions of uncertainty among participants. Notable instances include participants expressing hesitation, seeking clarification, or indicating a lack of confidence in certain aspects of the tasks. This behaviour was most seen during the beginning as the participants were still trying to figure out how the program works. An example of this was between students looking at all the options that the program gave them:

"11:07 P2: But then they mean the inside of the house or something. Or what? I don't know…What can you do to allow the maximum light into the house, through the windows? 11:16 P4: Yeah, like if the windows, this angle, there's more light coming in, I guess."

Another noticeable behaviour pattern was the participants' tendency to avoid complexity, as demonstrated in the statement:

"C2: we make like two stories? That's too much effort. Yeah, C1: we can. Sure, we can."

Additionally, participants frequently engaged in off-task conversations, diverting from the focus of the assignment, such as:

"C1: we can make a door! Yeah, how much does a human cost? C3: That's the real question.C2: [00:17:00] Since when are humans for sale? Well, for the entirety of history, to be honest. Okay, fair."

"09:14 P2: The house should be beautiful from the outside, what is like… beautiful? 09:25 P4: I like grey concrete. 09:29 P2: Me too 09:30 P1: Me too. I'm a minimalist."

This behaviour persisted across all rounds, indicating a consistent pattern of distraction and preference for simplicity.

Direct Effect of Uncertainty on Self-Competency

The linear regression analysis aimed at analysing the direct impact of uncertainty on self-competency and revealed significant insights. The model revealed a significant negative relationship between uncertainty and self-competency ($\beta = -0.25$, $p = 0.0124$). This indicates that as the level of uncertainty increased, participants reported lower levels of self-competency. Furthermore, the effect size ($R^2 = 0.15$) suggests that 15% of the variability in self-competency scores can be attributed to variations in uncertainty levels.

Effect of Self-Efficacy on Self-Competency

The results indicated a negative association ($\beta = -0.95$, $p = 0.0251$). This suggests that higher levels of self-efficacy were associated with lower reported levels of self-competency among participants. The effect size ($R^2 = 0.12$) indicates that 12% of the variability in self-competency scores can be explained by variations in self-efficacy.

Correlation between Uncertainty and Self-Efficacy

The correlation analysis revealed a correlation coefficient of 0. While this absence suggests no linear relationship, other moderating factors that might influence this relationship should be considered.

Moderation Analysis

The interaction between uncertainty and self-efficacy did not provide significant effects on self-competency ($\beta = -0.1192$, $p = 0.7985$). This indicates that the relationship between uncertainty and self-competency was not significantly influenced by self-efficacy.

Considering the interaction between uncertainty and self-efficacy across rounds, the coefficients remained non-significant.

ANOVA Analysis

The analysis of variance (ANOVA) explored the differences in self-competency across different groups. The results indicated no significant differences between groups ($F = 0.05$, $p = 0.985$), suggesting that the observed variations in self-competency were not attributed to group differences.

In summary, the detailed analysis of the results provides valuable insights into the complex interplay between uncertainty, self-efficacy, and self-competency among students in digital engineering tasks. The following "Discussion" section will delve into interpreting these findings and their implications for theory and practice.

Discussion

This study investigates the relationship between self-efficacy and reported self-competency in an uncertain environment within digital engineering tasks. The findings contribute small but valuable insights into how students navigate uncertainty and perceive their competence in digital engineering tasks.

It should be acknowledged that a single measurement of self-efficacy, a small participant pool, and poor and inconsistent audio/video material heavily impact the study's validity. The potential limitation of inaccurate measures, such as the uncertainty markers, raises concern about the interpretability of the results. It is important to recognize that the outcomes from the experiment may be constrained because of the employed measures, thus making it harder to draw definitive conclusions. Future research should address these limitations by improving the measuring tools and data.

The study supported two out of four hypotheses, revealing significant relationships between uncertainty, self-efficacy, and self-competency among students in digital engineering tasks. Notably, the direct effect analysis demonstrated a negative association between uncertainty levels and reported self-competency, indicating that heightened uncertainty corresponds to lower self-competency. This aligns with Dewey's (1934) assertion that uncertainty catalyses critical thinking and creative problem-solving. The negative association between self-efficacy and self-competency, asks for more research, as self-efficacy was only

measured once as a baseline and was not measured again with the other self-competency measure rounds.

Educational Practice and Policy Implications

In an educational context, understanding the complex relationship between uncertainty, self-efficacy, and self-competency provides insights for educators and policymakers. It suggests that creating a balance between challenging and uncertain tasks, while encouraging self-efficacy beliefs, may contribute to students' positive experiences and outcomes in digital engineering tasks. The insights can then be used by educators to design, for example, interventions that promote self-efficacy in the face of uncertainty, creating a better learning environment.

Limitations and Future Recommendations

While providing useful insights, this study is not without limitations. Acknowledging these shortcomings is important for understanding the research findings and prompt consideration for future improvements.

Self-efficacy Measured Only Once

One notable limitation is the single measurement of self-efficacy at the beginning of the experiment using the General Self-efficacy Scale (GSE) (Schwarzer & Jerusalem, 1995). This only provided a single measure point of the participants' self-efficacy levels before engaging in the experiment. The assessment of factors like "*self-efficacy*" could have significantly benefitted from a repeated measures approach to study the changes within the participants over time. This would allow for a better and more thorough examination of how self-efficacy and uncertainty evolve in digital engineering-task tasks.

For future research, it is recommended that to capture self-efficacy, it should be considered to implement multiple measurements throughout the experiment. This could involve assessing the GSE per session or activity, allowing for a more nuanced understanding of how self-efficacy evolves in response to the different phases of the experiment.

Insufficient Participant Pool

The study's sample size of 13 participants was too small and raised concerns about the statistical power and generalizability of the experiment. A larger sample size reduces the risk of Type I or Type II error (Banerjee et al., 2009). The limited diversity within the small participant pool also undermines the internal and external validity of the study, limiting the

generalizability of the experiment (Faber & Fonseca, 2014; Bhandari, 2023). Furthermore, no extra details were asked of the participants such as their nationality, age, or gender.

For future research, it is recommended to simply increase the sample size to strengthen the validity of the study.

Insufficient Video/Audio Material:

The quality and the quantity of the video/audio material collected varied across the groups. This impacted the quality of the qualitative analysis. For some groups some parts of the session were missing, making it harder to point the markers to their behaviour. While it was intended to capture the emotions and exchanges of uncertainty among participants, the lack of video/audio data limits the depth of these insights.

Due to the lack of reliable video and audio material, the variable ‘uncertainty’ could not be properly assessed. As a workaround, a replacement number had to be implemented based on the round number, the first round being the most uncertain and the final round being the least. This substitution, while necessary under the circumstances, introduces a potential source of bias and limits the precision of the uncertainty variable. It also hindered the use of the predefined markers proposed by Jordan et al., (2014). These intended markers were designed to capture nuanced expressions of uncertainty but could not be applied due to the inconsistent and incomplete nature of the recorded material. This limitation impacted the study’s ability to conclude the relationship between uncertainty, self-efficacy, and self-competency.

For future research, it is recommended to establish better recording conditions across all the sessions. This could be done by isolating the groups and making sure that each participant is visible in the camera frame. Moreover, providing individual microphones to participants can enhance the quality of the audio recordings, ensuring that their voices are accurately captured. By addressing these technical challenges, a more reliable dataset for the qualitative part of the data analysis can be ensured thereby strengthening the validity and interpretability of the findings.

The Level of the Task

A notable observation during the study was the participants' perceived ease of the tasks, which potentially led to a lower level of uncertainty. The participants consistently tended to avoid introducing complexity into their projects, indicating a reluctance to elevate the difficulty of the tasks. This reluctance was evident in the qualitative analysis, where

patterns emerged, showcasing that they often engaged in unrelated conversations, distracting themselves, and frequently opted for simpler approaches.

Conclusion

In conclusion, this study investigated the relationship between perceived self-competency in digital engineering tasks, self-efficacy, and uncertainty. As suggested by Dewey, uncertainty fosters critical thinking and innovative problem-solving. The results showed that uncertainty had a significant effect on self-competency. Furthermore, a negative correlation was found between perceived self-competency and self-efficacy.

Despite the limitations in the participant pool size and data quality, the study still offers valuable insights for educational improvement, with recommendations for future research. It emphasizes that encouraging high self-efficacy in digital engineering tasks enhances positive educational outcomes.

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Appendices

Appendix A. – General Self-Efficacy Scale

General Self-Efficacy Scale (GSE)

About: This scale is a self-report measure of self-efficacy.

Items: 10

Reliability:
Internal reliability for GSE = Cronbach's alphas between .76 and .90

Validity:
The General Self-Efficacy Scale is correlated to emotion, optimism, work satisfaction. Negative coefficients were found for depression, stress, health complaints, burnout, and anxiety.

Scoring:

	Not at all true	Hardly true	Moderately true	Exactly true
All questions	1	2	3	4

The total score is calculated by finding the sum of the all items. For the GSE, the total score ranges between 10 and 40, with a higher score indicating more self-efficacy.

References:
Schwarzer, R., & Jerusalem, M. (1995). Generalized Self-Efficacy scale. In J. Weinman, S. Wright, & M. Johnston, *Measures in health psychology: A user's portfolio. Causal and control beliefs* (pp. 35-37). Windsor, UK: NFER-NELSON.

General Self-Efficacy Scale (GSE)

	Not at all true	Hardly true	Moderately true	Exactly true
1. I can always manage to solve difficult problems if I try hard enough	☐	☐	☐	☐
2. If someone opposes me, I can find the means and ways to get what I want.	☐	☐	☐	☐
3. It is easy for me to stick to my aims and accomplish my goals.	☐	☐	☐	☐
4. I am confident that I could deal efficiently with unexpected events.	☐	☐	☐	☐
5. Thanks to my resourcefulness, I know how to handle unforeseen situations.	☐	☐	☐	☐
6. I can solve most problems if I invest the necessary effort.	☐	☐	☐	☐
7. I can remain calm when facing difficulties because I can rely on my coping abilities.	☐	☐	☐	☐
8. When I am confronted with a problem, I can usually find several solutions.	☐	☐	☐	☐
9. If I am in trouble, I can usually think of a solution	☐	☐	☐	☐
10. I can usually handle whatever comes my way.	☐	☐	☐	☐

Appendix B. – AIRE, Self-Regulation scale

APPENDIX A

Section 1
WHAT WAS IMPORTANT TO YOU IN REGARD TO THE GROUP EXERCISE?

1.1. What was your major **goal** regarding this group exercise? _____

_____

1.2. Apart from task completion, what **other things** have been important to you in this group exercise?

	not very important for me 1	2	3	a top priority for me 4
A. Get the highest possible mark, ideally a High Distinction	☐	☐	☐	☐
B. Make sure my grade is not going to be low because of the group	☐	☐	☐	☐
C. Learn as much as possible from others	☐	☐	☐	☐
D. Get new ideas from the group	☐	☐	☐	☐
E. Avoid being stressed	☐	☐	☐	☐
F. Not let the group down	☐	☐	☐	☐
G. Avoid looking incompetent	☐	☐	☐	☐
H. Have a good time, enjoy the experience	☐	☐	☐	☐
I. Make new friends, socialise with other students	☐	☐	☐	☐
J. Take personal responsibility for the work	☐	☐	☐	☐
K. Make sure I did not do more than others	☐	☐	☐	☐
L. Make sure everyone in the group contributed equally	☐	☐	☐	☐
M. Take the opportunity to practise my leadership skills	☐	☐	☐	☐

1.3. Which of the above have been the **most important to you** in this group exercise?

The most important First ☐ Second ☐

The least important ☐

Section 2
WHAT CHALLENGES DID YOU EXPERIENCE AS A GROUP ?

Below is a list of situations that you **may or may not have encountered** in your group and if so they would have **triggered strong feelings among (some) group members.** Please indicate for each of them, whether you experienced this in your group or not. If it happened, specify how big the challenge was, in your opinion.

Most of the situations below are described by a general statement followed by possible examples of how this might have happened. **The examples are not intended to describe the only way** the statements may be true. If the statement is true for you, and the example is not exactly how it happened in your group, please still rank the statement as you experienced it.

Please note that having to work through a challenge is not necessarily a negative experience. It may have turned into a positive experience and a successful outcome in the end.

It is assumed that each of these challenges would have triggered strong feelings among (some) group members

Our group experienced situation which triggered feelings where…

A. Our goals for the project were different.

For example - one/some people wanted to get a Distinction or High Distinction and others were just happy to get a Pass
- one/some people were so interested in the project that they were prepared to invest a huge amount of time but others were not interested.

It did not happen	*It was a small challenge*			*It was a big challenge*
0	1	2	3	4
☐	☐	☐	☐	☐

Our group experienced situation which triggered feelings where…

B. We had different priorities.

For example - Some people were more interested in socialising than getting on with the task.
- For some people, it was so important to have a pleasant atmosphere and friendly interactions that they were not prepared to question each other's views when discussing the task.

It did not happen	*It was a small challenge*			*It was a big challenge*
0	1	2	3	4
☐	☐	☐	☐	☐

Our group experienced situation which triggered feelings where…

C. We seemed to have incompatible styles of working.

For example - One/some people wanted to start working right away while others wanted to plan first and start to work after that.
- Others wanted to do other things first and work on the project later, saying that they always worked well under last minute pressure while others wanted to start as early as possible.

It did not happen	*It was a small challenge*			*It was a big challenge*
0	1	2	3	4
☐	☐	☐	☐	☐

Our group experienced situation which triggered feelings where…

D. We seemed to have different styles of interacting.

For example - one/some people were used to telling others (or others telling them) directly if they disagreed but others were uncomfortable with this and found this style of interaction confrontational
- one/some people were rather shy and others very outspoken
- two people were competing to be the group leader.

It did not happen	*It was a small challenge*			*It was a big challenge*
0	1	2	3	4
☐	☐	☐	☐	☐

Our group experienced situation which triggered feelings where…

E. People in our group did not connect very well with one another

For example - we had a different sense of humour
- we were not on the same wavelength
- our group found it very difficult to create a team atmosphere

It did not happen	*It was a small challenge*			*It was a big challenge*
0	1	2	3	4
☐	☐	☐	☐	☐

Our group experienced situation which triggered feelings where…

F. One/some people were not fully committed to the group project.

For example - they did not make attendance at meetings their priority.
- they did not do their share of the work
- they seemed to expect that others would cover for them

It did not happen	*It was a small challenge*			*It was a big challenge*
0	1	2	3	4
☐	☐	☐	☐	☐

Our group experienced situation which triggered feelings where…

G. People had very different standards of work.

For example - they said they could not find the information
- the quality of their work was unacceptable.

It did not happen	*It was a small challenge*			*It was a big challenge*
0	1	2	3	4
☐	☐	☐	☐	☐

Our group experienced situation which triggered feelings where…

H. Group members were not equal.

For example - Some tended to dominate, trying to impose their ideas, while others' didn't get a chance to contribute.
- Some people's opinions were not taken into account.

It did not happen	*It was a small challenge*			*It was a big challenge*
0	1	2	3	4
☐	☐	☐	☐	☐

Our group experienced situation which triggered feelings where…

I. Some people were easily distracted.
For example - they made and received phone calls on their mobiles during meetings
- they were interrupted by their friends
- they had other priorities at the time

It did not happen	*It was a small challenge*			*It was a big challenge*
0	1	2	3	4
☐	☐	☐	☐	☐

Our group experienced situation which triggered feelings where…

J. Our ideas about what we should do were not the same.
For example - One/some people had strong opinions of how we should proceed but others thought they were wrong.

It did not happen	*It was a small challenge*			*It was a big challenge*
0	1	2	3	4
☐	☐	☐	☐	☐

Our group experienced situation which triggered feelings where…

K. We differed in our understanding of the concepts/task.
For example - we were sometimes talking about different things even though we used the same words
- we had problems agreeing on what content to cover / ideas to include in our project
- our views were very different.

It did not happen	*It was a small challenge*			*It was a big challenge*
0	1	2	3	4
☐	☐	☐	☐	☐

Our group experienced situation which triggered feelings where…

L. We had different personal life circumstances or family / study & work commitments.
This made it very difficult
For example - to organise meetings
- for everybody to attend
- for people to stay long enough.
- to coordinate timetable

It did not happen	*It was a small challenge*			*It was a big challenge*
0	1	2	3	4
☐	☐	☐	☐	☐

Finally,

From the list above (A to L), please indicate below what you think were

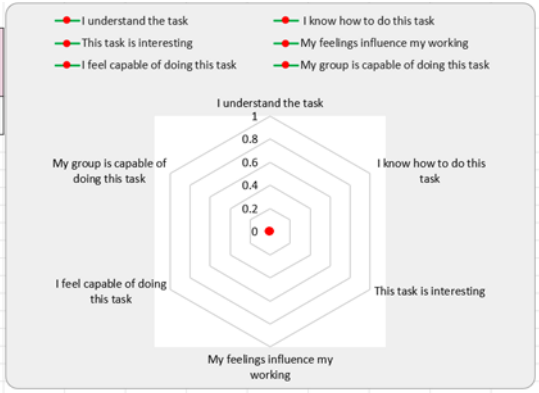
the two biggest challenges in your group (Insert letters): ☐ ☐

Appendix C. – SSRL Charts

Individual RADAR Chart

	I understand the task	I know how to do this task	This task is interesting	My feelings influence my working	I feel capable of doing this task	My group is capable of doing this task
Student 1	0	0	0	0	0	0

Likert Scales	
0	None
1	Low
2	Average
3	High
4	Very High

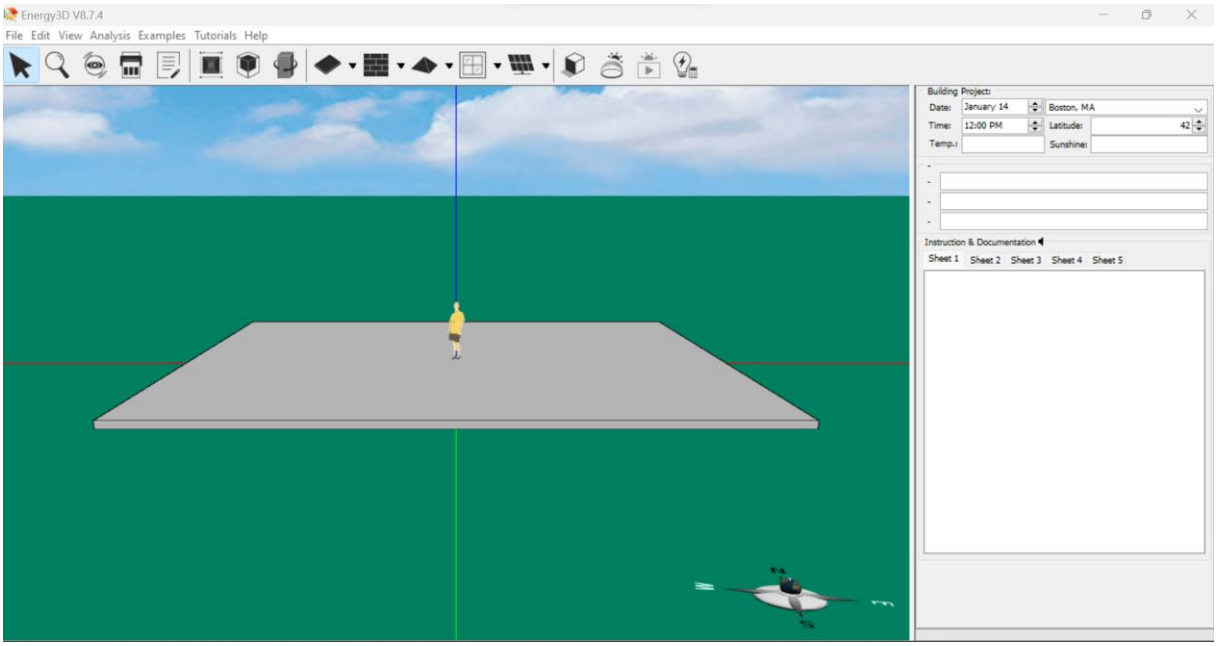


Appendix D. – Uncertainty Markers

Uncertainty Markers

Type of Uncertainty Marker	Description	Examples
Paralinguistic Markers		
rising prosody/intonation (Barr, 2003)		
Errors		
Disfluencies		
Hesitations, 5 types (Maclay & Osgood,1959)	unfilled pauses	silent pauses
	sounds of hesitation	"um", "er"
	filled pauses	"well"
	Repeats	
	false starts	
Hedges*		
Frequency	adverbs that refer to the probability of occurrence	often, seldom, never
Psychological	parenthetical adverbs that convey psychological uncertainty	expect, doubt
Ambiguous	modal verbs and auxiliaries that convey referentially ambiguous uncertainty	might, perhaps
Other Markers		
Questions: basic vs. wonderment (Berieter & Scardamalia, 1991)		"What do we do here?"
Approximators (Meaney, 2006)		"It's pretty long"
Statements of inability (Meaney, 2006)		"I don't know what to do"
Qualifiers (McFayden, 1996)		
Rephrasings (McFayden, 1996		
Self-reports of mental states that reflect metacognitive awareness (Anderson et al., 2001).		"I'm not sure" "I'm confused"

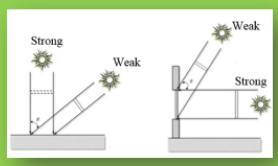
Appendix E. – Energy3D V8.7.4



Appendix F. – Information Trifold

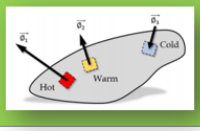
Solar Radiation

is all of the light and energy that comes from the sun (It's the sunlight!). The intensity of solar energy that strikes a surface depends on the sun's angle relative to the surface. The solar radiation input is the strongest when the surface directly faces the sun.



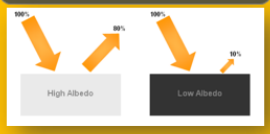
Heat Flux

is the rate of heat transfer at a given position and in a given direction. The figure shows the heat flux at different points on a surface. The heat map that appears after running an analysis in Energy3D corresponds to the heat flux.



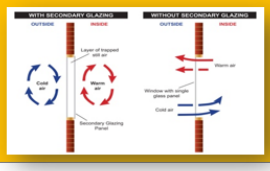
Albedo

is the ratio of the reflected radiation from a surface to the incident solar radiation. Albedo is zero for a perfectly black surface (black surface absorbs maximum solar radiation) and one for a perfectly white surface (white surface reflects maximum solar radiation).



Insulation

refers to the materials used to trap heat and slow down heat transfer. The construction industry commonly uses the R-value to measure insulation. The R-value represents the insulation's ability to resist heat transfer. The U-value is the inverse of the R-value, and is generally used for windows.



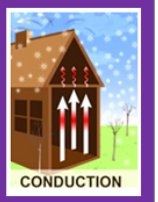
Direct, Diffuse, and Reflected Solar Radiation

Direct radiation is the solar radiation that travels to the surface without being absorbed or scattered. Diffuse radiation is the portion of solar radiation scattered or re-emitted by the atmosphere in all directions. Reflected radiation is radiation bounced off of the ground. Adding trees can decrease the amount of reflected radiation hitting the house.

Heat Transfer

Can occur via three processes:

In the process of thermal conduction, thermal energy passes from molecule to molecule through direct contact.



In the process of thermal convection, thermal energy passes from one position to another through the flow of a fluid (liquid or gas).

In the process of thermal radiation, thermal energy is transferred by light. Trees around the building can help lower radiative and convective heat transfer.

Reference Guide for Building your Net Zero Home

1. *Heat Transfer*
2. *Solar radiation*
3. *Heat flux*
4. *Albedo*
5. *Insulation*
6. *Direct, diffuse and reflected solar radiation*

Appendix G. – Informed Consent

Name _____

Code _____

Information Sheet

The purpose of this research is to unravel the relationship between *self-efficacy*, self-regulation*** and uncertainty management within collaborative learning environments.

During this experiment, you will create an energy-efficient house with a small group. More information about the assignment can be found in the assignment form.

There are no risks associated with this research and this research project has been reviewed and approved by the BMS Ethics Committee

If you would like to withdraw from the study at any point please contact one of the researchers on

this project (details mentioned below).

During the research no personal information will be collected. Audio and video recordings will be made but they will not be able to identify the person on the recording. The audio data will be transcribed into text before being analysed, any personal information will be anonymised during this process. All data will be retained until the end of the project. Safety will be ensured by anonymizing all the data and only the researchers mentioned in this list will have access to the data.

Researchers:

Ilayda Hotamış e.i.hotamis@student.utwente.nl
Julia Knot j.r.knot@student.utwente.nl
Hannie Gijlers a.h.gijlers@utwente.nl
Chandan Dasgupta c.dasgupta@utwente.nl

**Self-efficacy refers to an individual's belief in his or her capacity to execute behaviours necessary to produce specific performance attainments.*

*** Self-regulation is the ability to control one's behavior, emotions, and thoughts in the pursuit of long-term goals.*

Name _____

Code _____

Consent Form for Uncertainty in digital engineering-tasks and how it influences self-efficacy in students

YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated [22/11/2023], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	□	□
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	□	□
I understand that taking part in the study involves answering 2 questionnaires, being video-recorded which will be destroyed at the end of the study), being audio-recorded (and that this audio will be transcribed as text)	□	□
	□	□
Use of the information in the study		
I understand that information I provide will be used for a bachelor's thesis project		
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	□	□
I agree that my information can be quoted in research outputs	□	□

I agree to be audio recorded

□ □

I agree to be video recorded

□ □

Name _____

Code _____

Signatures

_____ _____ _____

Name of participant Signature Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting. □ □

_____ _____

_____

Researcher name Signature Date

Study contact details for further information: [*Name, email address*]

Ilayda Hotamış e.i.hotamis@student.utwente.nl

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Hannie Gijlers a.h.gijlers@utwente.nl

Chandan Dasgupta c.dasgupta@utwente.nl

Contact Information for Questions about Your Rights as a Research Participant (

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other

than the researcher(s), please contact the Secretary of the Ethics Committee/domain Humanities & Social Sciences of the Faculty of Behavioural, Management and Social Sciences at the University of Twente by ethicscommittee-hss@utwente.nl

Appendix H. – R-Code

```
# Install and load necessary packages
install.packages(c("tidyverse", "readxl"))
library(tidyverse)
library(readxl)



# Load the Excel file
excel_file <- read_excel("Dataset.xlsx")

# Step 1: Direct Effect of Uncertainty on Self-Competency
model_direct <- lm(SelfCompetency ~ Uncertainty, data = excel_file)
summary(model_direct)

# Step 2: Effect of Self-Efficacy on Self-Competency
model_self_efficacy <- lm(SelfCompetency ~ SelfEfficacy, data = excel_file)
summary(model_self_efficacy)

# Step 3: Correlation between Uncertainty and Self-Efficacy
correlation_coefficient <- cor(excel_file$Uncertainty, excel_file$SelfEfficacy)
correlation_coefficient

# Step 4: Moderation Analysis
model_moderation <- lm(SelfCompetency ~ Uncertainty * SelfEfficacy, data =
excel_file)
summary(model_moderation)
```

```
## effects per round


# Step 1: Direct Effect of Uncertainty on Self-Competency for Round 1
model_direct_round1 <- lm(SelfCompetency ~ Uncertainty + SelfEfficacy +
Uncertainty:SelfEfficacy, data = filter(excel_file, Round == 1))
summary(model_direct_round1)

# Step 2: Direct Effect of Uncertainty on Self-Competency for Round 2
model_direct_round2 <- lm(SelfCompetency ~ Uncertainty + SelfEfficacy +
Uncertainty:SelfEfficacy, data = filter(excel_file, Round == 2))
summary(model_direct_round2)

# Step 3: Direct Effect of Uncertainty on Self-Competency for Round 3
model_direct_round3 <- lm(SelfCompetency ~ Uncertainty + SelfEfficacy +
Uncertainty:SelfEfficacy, data = filter(excel_file, Round == 3))
summary(model_direct_round3)

# Step 4: Effect of Self-Efficacy on Self-Competency for Round 1
model_self_efficacy_round1 <- lm(SelfCompetency ~ SelfEfficacy, data =
filter(excel_file, Round == 1))
summary(model_self_efficacy_round1)

# Step 5: Effect of Self-Efficacy on Self-Competency for Round 2
model_self_efficacy_round2 <- lm(SelfCompetency ~ SelfEfficacy, data =
filter(excel_file, Round == 2))
summary(model_self_efficacy_round2)

# Step 6: Effect of Self-Efficacy on Self-Competency for Round 3
```

```
model_self_efficacy_round3 <- lm(SelfCompetency ~ SelfEfficacy, data =
filter(excel_file, Round == 3))
summary(model_self_efficacy_round3)

# Step 7: Correlation between Uncertainty and Self-Efficacy for Round 1
correlation_round1 <- cor(filter(excel_file, Round == 1)$Uncertainty, filter(excel_file,
Round == 1)$SelfEfficacy)
correlation_round1

# Step 8: Correlation between Uncertainty and Self-Efficacy for Round 2
correlation_round2 <- cor(filter(excel_file, Round == 2)$Uncertainty, filter(excel_file,
Round == 2)$SelfEfficacy)
correlation_round2

# Step 9: Correlation between Uncertainty and Self-Efficacy for Round 3
correlation_round3 <- cor(filter(excel_file, Round == 3)$Uncertainty, filter(excel_file,
Round == 3)$SelfEfficacy)
correlation_round3

# Step 10: Moderation Analysis for Round 1
model_moderation_round1 <- lm(SelfCompetency ~ Uncertainty * SelfEfficacy, data =
filter(excel_file, Round == 1))
summary(model_moderation_round1)

# Step 11: Moderation Analysis for Round 2
model_moderation_round2 <- lm(SelfCompetency ~ Uncertainty * SelfEfficacy, data =
filter(excel_file, Round == 2))
summary(model_moderation_round2)

# Step 12: Moderation Analysis for Round 3
```

```
model_moderation_round3 <- lm(SelfCompetency ~ Uncertainty * SelfEfficacy, data =
filter(excel_file, Round == 3))
summary(model_moderation_round3)

##additional considerations

# Descriptive Statistics
summary(excel_file$SelfCompetency)
summary(excel_file$Uncertainty)
summary(excel_file$SelfEfficacy)

# ANOVA

anova_model <- aov(SelfCompetency ~ Group, data = excel_file)
summary(anova_model)
```