Student Engagement with Flipped Classroom Mathematics Video Lectures: An Exploratory Study in Secondary School

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Abstract

This study explores students' engagement with video lectures and quizzes created for use in flipped classroom activities in a mathematics course in a Dutch secondary school. In flipped classroom context videos prepare students for interaction in the actual classroom setting, by presenting content that enables them to participate in classroom activities. However, little is known about the engagement of secondary students with videos. The present study explores this. The research question states: How do secondary school students engage with online video lectures? Dutch 9th-grade pre-university Technasium students (N=39) participated in mathematics class. Behavioral engagement is observed using the Leuven Scale. Responses to quiz questions and students' reflections are collected in an online learning environment. Results show low to moderate engaging behavior while watching videos, high scores on low-engagement quiz questions and low on high-engagement questions. Students' reflections report low to moderate engagement, scoring significantly low on note-taking. This exploratory study has no control group. The discussion provides a first insight into student engagement in this school and suggests design options for implementing video lectures in secondary mathematics education. These options include utilizing quiz question data to provide differentiated instruction and placing increased emphasis on the importance of note-taking.

Keywords: flipped classroom, engagement, secondary school, video instruction, mathematics

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Teaching with the flip the classroom approach has become more evident in education over the past ten years (Bergmann & Sams, 2012; van Alten et al., 2019). In this approach, students prepare with learning content out of class and engage in various learning activities in class. For example, they watch online videos of the course content as homework and engage in guided problem-solving, and class discussions during in-class time (Bhagat et al., 2016). Especially during the COVID pandemic, schools relied on video lectures to teach students. In post-pandemic times, a Dutch secondary school raised the question of whether they could implement videos in their flipped classroom courses. They wish to explore the added value of these videos, and what could be expected of the students after watching video lectures. Research shows that high student engagement with the learning content increases students' learning (Chi & Wylie, 2014). Positive results on students' grades in higher education after flipped classroom teachings, are reported by Hibbard et al. (2016). Although guidelines for designing instructional videos are described by (Van Der Meij & Van Der Meij, 2013), the engagement of secondary school students with video lectures and quizzes through flipped classroom teaching is, to the best of our knowledge, not been studied before (Muir, 2021; van Alten et al., 2019). Therefore, the behavioral, cognitive, and emotional engagement (Zhang et al., 2022) of secondary students with videos and quiz questions will be explored in this study. Collecting insight into student engagement might help the school decide whether they continue offering video lectures in what way and for which purpose. Furthermore, it provides guidelines for improving future video lectures and quiz questions implemented in flipped classroom teaching in this school.

This study starts to explore the engagement of secondary school students during mathematics lessons delivered through video lectures and quiz questions. Flipped classroom video lectures will be designed and introduced in an online learning environment, accompanied by quiz questions specific to the mathematics course. The purpose of this study is to explore student engagement in this secondary school during mathematics video lectures from three angles. Firstly, by observing current students' behavior, secondly, by testing the skills and knowledge acquired, and lastly by examining students' experiences with video lectures. This leads to insight into the current student engagement with videos and to suggestions for designing high-engagement mathematics video lectures.

Theoretical Framework

Flipping the Classroom

Researchers are continuously investigating the flipped classroom approach. Flipping the classroom entails students learning the concepts at home, to prepare for in-class time. For example, by watching online video lectures as homework or reading the materials provided (Davies et al., 2013; O'Flaherty & Phillips, 2015). Students are able to prepare themselves at their own pace in their own time (Song & Kapur, 2017). In-class time is used "to participate in meaningful learning activities, instructor-guided problem solving, and discussions" (Bhagat et al., 2016, p.134). This allows for more active participation of students during class, as students practice their learning, and ask questions to the teacher (McCord & Jeldes, 2019). In-class time should align with student's learning needs, and encourage higher-order learning by guiding knowledge application and critical thinking (Jensen et al., 2015; O'Flaherty & Phillips, 2015). Other effects of the flipped classroom are an increase in student engagement, more student-teacher and peer interactions, increased responsibility for their own learning (Hibbard et al., 2016), personalizing instruction fitting student's learning for developing problem-solving strategies and higher order of critical thinking (Davies et al., 2013; Song & Kapur, 2017).

Previous studies on various higher education courses found positive reactions to the flipped classroom approach. Davies et al. (2013) researched technology in the flipped classroom for a statistics course, concluding that the flipped classroom facilitated the learning needs of students as it allowed for differentiation of instruction and supported the students' motivation. The study by Hibbard et al. (2016) found higher grades for chemistry students taught through flip the classroom compared to traditional teaching. However, students' expectations, attitudes toward the more problem-based team learning, and time management of students were also important factors for the exam results. Jensen et al. (2015) conducted a study for university students on an active traditional and active flipped classroom approach by engaging the students, resulting in an equal level of conceptual learning. These studies were all done in higher education, and the results might be different for secondary school students. The active teaching approach seems to be an important factor in student engagement.

Engage to Learn

Traditional lectures have been given in a one-size-fits-all manner, allowing limited time for active learning activities (van Alten et al., 2019). According to van Alten et al., this hindered student engagement with the learning materials and therefore their constructive

learning, although this is critical for developing a deeper understanding of the course. Engagement in secondary school could positively affect students' learning experiences and academic results (Zhang et al., 2022). Janosz (2012) concluded that "engagement strongly predicts achievement and learning competencies" (p. 696). Student engagement in secondary school has a lasting impact on their future career, but the lack of engagement predicted drop-outs. Engagement is a multidimensional construct to understand student involvement across education levels (Zhang et al., 2022), measured by three dimensions, behavioral, emotional, and cognitive dimension. Ferre Laevers (2016), described characteristics of engagement as being 'highly concentrated, intrinsically motivated and driven to get started. Another characteristic is the intense mental activity, where people work at the border of their capabilities' (p. 16). Chi and Wylie (2014) defined knowledge engagement as 'the amount of cognitive engagement that can be detected by smaller-grained behavioral activities *while students learn*' (p. 219). They explained four different levels of engagement, called the ICAP framework (see Table 1), describing the passive, active, constructive, and interactive behavior of the student while presented with learning materials.

Firstly, passive engagement is characterized by receiving information via listening, reading, or watching a video without doing anything else. New knowledge was stored in this specific context, without integration in different contexts and the student could recall this information in the same context. Secondly, active engagement is defined by the movements of the students, such as taking notes by copying the content while listening, highlighting important sentences, or manipulating the video by pausing or rewinding. Active engagement guided students to integrate new knowledge into their existing knowledge schemes (Chi & Wylie, 2014). An assignment causing active engagement could be choosing a correct explanation or elaboration among incorrect options via multiple-choice questions. Thirdly, constructive engagement is characterized by the addition of knowledge that is beyond the provided content. Students have generated new ideas, by notetaking in their own words, creating hypotheses and causal relations, reflecting on their work, and asking questions. By providing the students with incomplete solutions, students are required to reflect on what is known and what should be added to complete the solution. Lastly, the interactive mode of engagement is defined as constructive interaction between students. Constructive interaction includes discussions, asking and answering questions, and explaining concepts to one another, with co-created knowledge as a result. Questions students asked themselves are: 'How can I respond to my friend regarding the correctness of his/her explanation?' and 'How can I modify my friend's solution and explanation?' (Chi & Wylie, 2014, p. 233). Based on their

research, Chi and Wylie conclude that 'as students become more engaged with the learning materials, from *passive* to *active* to *constructive* to *interactive*, their learning will increase' (Chi & Wylie, 2014, p. 219). Activities should be challenging at the level of students' capabilities, which activates high student engagement resulting in the development of new skills (Laevers et al., 2016). Keeping students engaged is the core of flipped classroom lessons and should be a reason for secondary schools to evaluate their course activities on the level of engagement.

Flipped Classroom Video Lectures

Over 72000 hours of new educational videos are uploaded on YouTube, every day (Ceci, 2022; Ten Hove & Van Der Meij, 2015). Watching videos for education has become popular among millennials (students born between 1982 and 2005) (Rana et al., 2017), and videos have been widely available on the internet. Different companies, such as Khan Academy; professionals, such as teachers and scientists; and amateurs created these videos. Students have selected videos as resources for studying and teachers appointed videos to prepare for class.

Table 1

Overview of the ICAP Framework (Chi & Wylie, 2014, p. 228)

CATEGORY *Characteristic*	PASSIVE *Receiving*	ACTIVE *Manipulating*	CONSTRUCTIVE *Generating*	INTERACTIVE *Dialoguing*
Example activities	Listening to explanations; Watching a video	Taking verbatim notes; Highlighting sentences	Self-explaining; Comparing and contrasting	Discussing with a peer; Drawing a diagram with a partner
Knowledge-change processes	Isolated "storing" processes in which information is stored episodically in encapsulated form without embedding it in a relevant schema, no integration	"Integrating" processes in which the selected & emphasized information activates prior knowledge & schema, & new information can be assimilated into the activated schema.	"Inferring" processes include: integrating new information with prior knowledge; inferring new knowledge; connecting, comparing & contrasting different pieces of new information to infer new knowledge; analogizing, generalizing, reflecting on conditions of a procedure, explaining why something works.	"Co-inferring" processes involve both partners taking turns mutually creating. This mutuality further benefits from opportunities & processes to incorporate feedback, to entertain new ideas, alternative perspectives, new directions, etc.
Expected changes in knowledge	New knowledge is stored, but stored in an encapsulated way.	Existing schema is more complete, coherent, salient, and strengthened.	New inferences create new knowledge beyond what was encoded, thus existing schema may become more enriched; procedures may be elaborated with meaning, rationale and justifications; and mental models may be accommodated; and schema may be linked with other schemas.	New knowledge and perspectives can emerge from co-creating knowledge that neither partner knew.
Expected cognitive outcomes	Recall: knowledge can be recalled verbatim in identical context (e.g., reuse the same procedure or explanation for identical problems or concepts).	Apply: knowledge can be applied to similar but non-identical contexts (i.e., similar problems or concepts that need to be explained)	Transfer: knowledge of procedures can be applied to a novel context or distant problem; knowledge of concepts permit interpretation & explanations of new concepts.	Co-create: knowledge and perspectives can allow partners to invent new products, interpretations, procedures, and ideas.
Learning outcomes: ICAP	Minimal understanding	Shallow understanding	Deep understanding, potential for transfer	Deepest understanding, potential to innovate novel ideas

An empirical study by Guo et al. (2014) evaluated four ways of creating video lectures: recordings of PowerPoint presentations, screen recordings of worked examples on drawing tables, recordings of classroom lectures, and recordings of a teacher with PowerPoint slides on a screen. They investigated these four designs for video lectures and created several recommendations for video instructions based on their outcomes. The focus was recording university student engagement during video lessons with their attempts to solve assessment problems. Based on their research, the following recommendations were made: to maintain engagement videos should not be longer than 6 minutes, big chapters should be divided into smaller topics; add the instructor on the screen as his appearance created more engagement by the students; for recorded tutorials, a continuous motion and flow of information or steps to take in a worked example were important; speaking in a fast-paced and enthusiastic manner is preferred over slowing down the pace, as students can pause and rewind the lecture if they miss any information. In addition, a study by Hew and Lo (2020) described guidelines for the best video instructions. They designed six different micro-lectures on the topic of Arithmetic and Geometric Sequences and their Summations, all adhered to the same video guidelines: highlighting keywords on screen; creating well-defined videos, not longer than 6 minutes each; and using personalized wording instead of formalized wording, meaning "this is how you do it" instead of "this is how one does it" (Hew & Lo, 2020, p. 852). The preferred designs were the PowerPoint video with the teacher's talking head, the recorded classroom lecture, and the Khan-style with the teacher's talking head with written step-by-step problem-solving. In all videos, a step-by-step explanation of the solutions was presented. Further research by Hew and Lo on these three video styles showed no significant difference in the students' performance of recalling information or their application of the information given in the videos. Hew and Lo investigated in addition the ability to recall and apply the content of the video using quiz questions and found that the quiz questions facilitated the application of the material significantly better than the copying of worked answers. Van der Meij and Böckmann (2021) argued that the addition of quiz questions positively affects active student engagement and learning. Eight guidelines for designing instructional videos by H. van der Meij and J. van der Meij (2013) are found in Table 2 and are used for designing video lectures in this study.

Research Question and Expectations

The aim of this study is to investigate students' engagement with video lectures, as part of the flipped classroom teaching approach. A case study is designed to examine the

engagement of 9th-grade students, with mathematics video lectures. The research question states: How do secondary school students engage with online video lectures? This research question is supported by three sub-questions. Firstly, what behavioral engagement do students show while watching the video lectures? Qualitative measures through classroom observations are taken and analyzed to answer this question. Secondly, quantitative data is collected through knowledge tests on the learning content to answer the question: How does interaction with the learning content reflect students' engagement? And lastly, how do students reflect on their engagement with the learning materials? Qualitative data through a questionnaire is collected and analyzed.

The behavioral student engagement is expected to be moderate to highly engaged since flipped classroom teaching requires students to be actively engaged (Hibbard et al., 2016; van Alten et al., 2019). Based on the conclusion by Schultz et al. (2014), students prefer simple concepts explained in video lessons and more difficult concepts explained in class. This outcome may be seen in the engagement levels of Chi and Wylie (2014) in relation to the learning outcomes. Students might get high scores on passive and active questions, by simply recalling and applying what is taught in the video, whereas constructive and interactive questions require a deep understanding of the content and transferring knowledge from previously taught materials. The positive effects of quiz questions as argued by van der Meij and Böckmann (2021), suggest positive responses to quiz questions in video lectures.

Overall it is expected that students' engagement with online learning videos is high, based on the literature described above. Firstly, students' behavior displays high behavioral engagement when they are concentrated and challenged by the learning materials, scoring level 4 on the Leuven Scale of Involvement. Secondly, it is expected that students score well on the interaction with the passive and active learning materials but miss the explanation of more difficult concepts in class, which they should ask for when needed. Lastly, reflection by the students on their engagement might show a high level of engagement, since these students are becoming self-regulated learners and are familiar with student-centered teaching methods.

Table 2

Guidelines for the Design of Instruction Videos (H. van der Meij & J. van der Meij, 2013)

Guideline 1: Provide easy access
Guideline 1.1: Craft the title carefully
Guideline 2: Use animation with narration
Guideline 2.1: Be faithful to the actual interface in the animation
Guideline 2.2: Use a spoken human voice for narration
Guideline 2.3: Action and voice must be in sync
Guideline 3: Enable functional interactivity
Guideline 3.1: Pace the video carefully
Guideline 3.2: Enable user control
Guideline 4: Preview the task
Guideline 4.1: Promote the goal
Guideline 4.2: Use a conversational style to enhance perceptions of task relevance
Guideline 4.3: Introduce new concepts by showing their use in context
Guideline 5: Provide procedural rather than conceptual information
Guideline 6: Make tasks clear and simple
Guideline 6.1: Follow the user's mental plan in describing an action sequence
Guideline 6.2: Draw attention to the interconnection of user actions and system reactions
Guideline 6.3: Use highlighting to guide attention
Guideline 7: Keep videos short
Guideline 8: Strengthen demonstration with practice

Method

Participants and Design

The participants in this study were selected using convenience sampling from two classes of 9th-grade Dutch students in the pre-university track of secondary education who were enrolled in the mathematics course. This specific secondary school offered a Technasium track, which is an active and engaging program that includes an additional Research & Design course next to the regular curriculum. This course focused on conducting research on practical problems and designing solutions. The projects tailored the students' educational level, gradually progressing towards a higher professional or university level for

their final thesis. The primary objective was to prepare students for science-related educational programs, exposing them to various professions and scientific challenges. These projects were developed based on actual problems faced by technical companies, governments, or organizations (Leijenaar, n.d.). The project criteria emphasized teamwork, creativity development, and out-of-the-box thinking, which aligned with the principles of constructive and interactive engagement, as described by Chi and Wylie (2014).

With respect to the participants, 39 students were Technasium students (64% male, 33% female, and 3% missing). The students were between 13 and 15 years old (M = 14.51; SD = 0.51). The mean math grade was 6.61 (n = 33; SD = 1.13) and the mean Technasium grade 7.42 (n = 33; SD = 0.72). Ethical approval was given by the University of Twente. Parents or caregivers gave passive consent (see Appendix B), and the students gave active consent via the online questionnaire (see Appendix C).

This study was an exploratory study, observing two similar classes, it explored the level of student engagement with video lectures for the mathematics course, as part of the flipped classroom approach. Procedural data were collected during class. The behavioral engagement was gathered using the Leuven Scale of Involvement. The interactions with the learning content were determined by mathematics quiz questions, and subjective data were collected through a questionnaire.

Materials

This study consisted of different materials that were used to answer the research questions. Descriptions of the mathematics content, the design of the video lectures, and the engaging quiz questions were given. To assess the engagement, an explanation of the quiz questions scoring criteria, the Leuven Scale, and the questionnaire were provided. Finally, the assessment and learning environment were described.

Mathematics Content

The planning of the school required teaching the topic of simplifying equations for grade 9. The instruction book Getal & Ruimte (Dijkhuis, 2021) was used. The first lesson taught about chapter 6.1, where theory A focused on the order of operations when calculating mathematical formulas and theory B addressed binominal and trinomial formulas. The second lesson taught about chapter 6.2, where theory A was about simplifying fractions by factorizing, and theory B described adding, subtracting, multiplying, and dividing similar and non-similar fractions.

Design Video Lectures

The video lectures were designed according to the guidelines described in section Flipped Classroom Video Lectures. The videos were recorded in 4K quality, and the audio was recorded on a separate device using a microphone. The script of the lectures is found in Appendix D. Video 6.1A lasted 2.07 minutes (Student.utwente, 2023a), video 6.1B was 2.15 minutes (Student.utwente, 2023b), 6.2A was 2.55 minutes (Student.utwente, 2023d) and video 6.2B lasted 4.24 minutes (Student.utwente, 2023c).

Engagement Quiz Questions

Each chapter consisted of two video lectures and four quiz questions to facilitate learning the content, as described by Hew and Lo (2020). These four questions were designed according to the ICAP framework (Chi & Wylie, 2014). Each question represented one of the four modes of engagement and was taken from the worked examples in the book or homework exercises. These modes were designed categorically, therefore the level of engagement was determined per mode, based on the percentage of correct answers. 50% represented a moderate engagement, below 25% was a low engagement, and above 75% was a high engagement.

The questions, answers, and assessment rubric for lessons one and two can be found in Table 3, Table 4, and Table 5. The latter described the deductive coding scheme, developed to assign points to open-ended questions. The questions in Dutch were found in the scripts of the videos (see Appendix D). The videos and the questions were implemented in the online learning platform Graasp. The closed-ended questions ABCD were collected as 1234 in Graasp. Unanswered questions were described as 0, and translated to ‘NA’ using RStudio. Open-ended questions were given points manually, based on the deductive coding scheme as described in Table 5. After the data collection, the try-out logins of the researcher were taken out manually. All logins by the students were set to the same nickname format: student000. Nicknames starting with a capital S were set to a lowercase s, if nicknames contained a space between student_000 the space was removed, and nicknames that contained the number only are completed with ‘student’.

Leuven Scale for Involvement

The Leuven Scale for Involvement was used to assess the overall engaging behavior of students while watching video lectures in class (Daems et al., 2005). This validated instrument ‘indicates how a person is doing and what the visible effect of the method, approach or pedagogy is’ (Centre for Experiential Oriented Education, n.d.). Signals to

measure the involvement were, for example, facial expressions and body language. Also, the concentration of a student, their energy, reaction time, precision, creativity, and satisfaction were taken into account. These signals are combined into one five-point scale, scoring from ‘1: Extremely low’ to ‘5: Extremely high’, measuring one item: ‘Engagement’. The moderate or average engagement was represented by level 3: ‘Moderate’. Levels 1 and 2 were considered as low engagement, level 3 as moderate or average engagement, and levels 4 and 5 as high engagement. A full description of the Leuven Scale and the scoring protocol can be found in Table A1 and an article by Laevers et al. (2005). Table E1 showed the recording schema, in which random students were observed on the spot in the classroom and given a score for their behavior based on the Leuven Scale. Since the observations were randomly conducted on the spot, taken from different angles, and no other observer was available, it was not possible to determine the interrater agreement. The guideline suggested observing an individual student for 40 to 120 seconds.

Table 3

Questions with video lectures 6.1A and 6.1B

Question number	ICAP mode	Reason	Question	Option answers	Answers
1.1	Passive	Recalling spoken and written information from the video	" Do multiplication before exponents"	True (1) False (2)	The correct answer is 'False' (2), the order of operations rule demands calculating with exponents first, before multiplication
1.2	Active	Choosing the correct answer from a set of options	Simplify $(2q-3)^2 - 3q(q-4)^2 =$	a: $13q^2 - 12q + 9$ (1) b: $-3q^3 - 20q^2 + 36q + 9$ (2) c: $-3q^3 + 28q^2 - 60q + 9$ (3)	The correct answer is C (3). A makes a mistake with the brackets and B makes a mistake with the $-3q$
1.3	Constructive	Transfering knowledge to a new situation and finishing an incomplete example	Simplify $(3x+2)^3 =$	(____)(____)^2 = ___	The correct answer is $27x^3 + 54x^2 + 36x + 8$
1.4	Interactive	Responding constructively to a peer (on paper)	Your friend started on the following question, but he got stuck. What advice would you give him in order to solve the problem? His attempt is: $(x+y+3)(x-y-3) = x^2 - yx - 3x - y^2 - 3y - 9$ $= x^2 - y^2 - yx - 3x - 3y - 9$	This is an open question	The correct answer contains advice about carefully multiplying each component of the first term with each component of the second term. He forgot to multiply $y \times x$, $3 \times x$ and $3 \times -y$

Table 4

Questions with video lectures 6.2A and 6.2B

Question number	ICAP mode	Reason	Question	Option answers	Answers
2.1	Active	Applying the knowledge	Simplify $\frac{12abc}{-4ac}$ =	a: $-3b$ (1) b: $\frac{12b}{-4}$ (2) c: $3b$(3)	The correct answer is answer A (1). B is incorrect as $\frac{12b}{-4}$ can be simplified to $-3b$. C is incorrect as the minus is missing.
2.2	Interactive	Cocreating newly acquired knowledge is needed to answer this question.	The example shown in the video is the same as example b from the book. We have simplified $p = \frac{q^2+6q-7}{2q-2}$ to $p = \frac{1}{2}q + 3\frac{1}{2}$. Explain why this simplification is incorrect for q=1.	This is an open question	Filling in q=1 in the original formula results in dividing by 0, which is not allowed or possible.
2.3	Passive	Recalling what was spoken and written in the video	" Dividing by a fraction is the same as multiplying by the inverse of that fraction"	True (1) False (2)	True (1)
2.4	Constructive	Transferring new information to a new context	Simplify $\frac{a}{3} - 2a$ =	a: $-\frac{5a}{3}$ (1) b: $-1\frac{2}{3}a$ (2) c: $-\frac{a}{3}$ (3) d: $\frac{2}{3}a^2$ (4)	The correct answer is answer B (2). A is incorrect as it can be simplified to B. C is incorrect because the fractions have to be made similar before subtracting. D is incorrect as one cannot do the same as with multiplication.

Table 5

Coding Scheme for Written Answers Video Questions

Question	Type of written answer	Description	Example
6.1 3	Answer provides (steps towards) the correct answer (1)	The brackets are correctly simplified and the end answer is correct	=27x^3 + 54x^2 + 36x + 8
	Incorrect calculation steps	The rules of order of calculation are not followed	= 27^3+8
	No answer given (NA)	An empty field indicates that no answer is given. The value will be set to NA	
6.1 4	Answer provides constructive hints to help the friend to find the correct answer (1)	Hints can identify missing elements, point out mistakes, and/or provide suggestions for a correct method to answer this question	He forgot to multiply each component of the first term with each component of the second term OR: Drawing lines to check if all elements are correctly multiplied
	Answer does not provide constructive hints and will not help to find the answer (0)	Hints are not based on the theory taught in this chapter, are applied incorrectly, or based on irrelevant ideas	Calculating on alphabetical order.
	Other (0)	Hints based on topics not related to this question or to the content of this chapter	He should pay better attention in class
	No answer given (NA)	An empty field indicates that no answer is given. The value will be set to NA	
6.2 2	Answer is based on theory that dividing by 0 is not allowed (1)	The answer indicates that the denominator becomes 0, and that is not allowed	Dividing by 0 is not possible.
	Answer does not indicate that dividing by 0 is not allowed (0)	The answer focuses only on the numerator or on the simplified formula	q=1/2
	Other (0)	Answer is not relevant to the content of the question	?
	No answer given (NA)	An empty field indicates that no answer is given. The value will be set to NA	

Engagement and Design Questionnaire

The questionnaire is not part of the video lectures but is designed to collect quantitative and qualitative data on three factors: student engagement, video lecture design, and background information about the participants. The questions about the engagement were designed using Chi and Wylie's ICAP framework (2014), (see Table 6) and answered on a 5-point Likert scale with 'strongly disagree' to 'strongly agree'. An example item regarding interactive engagement stated 'I have discussed the explanation of the video with my classmates'. A moderate engagement per engagement mode was set to the middle of the Likert scale, represented by 3. A low engagement was represented by 1 to 2 and a high engagement by 4 to 5. The constructs of active and constructive engagement consisted of four items. Therefore, Cronbach's alpha was calculated. The items represented the constructs questionably since Cronbach's alpha was 0.602 for active engagement and 0.516 for constructive engagement.

The questions about the design of the video were answered on a 3-point Likert scale, where the words of the scale had been designed to give appropriate answers to each question. An example stated 'The length of the video was: ', with these possible answers 'too long', 'perfect', and 'too short'. Another item was: 'Being able to see the teacher speak in the video was: ', answered by 'unnecessary', 'neutral', and 'convenient'. Lastly, some background questions provided information about their gender, age, and grades for mathematics and Technasium (if applicable). The complete questionnaire was presented in Appendix F. This questionnaire was translated into Dutch and checked by Professor Hannie Gijlers (see Appendix G). The design of questions and answers was carefully chosen, using the options in the assessment environment.

Assessment Environment

Graasp.eu has been an online learning platform and part of the Go-lab ecosystem. This authoring learning tool was developed to support 'innovative learning technologies in STEM education'(Go-Lab, n.d.). Teachers and researchers created a learning environment by uploading videos and adding questions and questionnaires and were able to collect interaction data. The students accessed the environment through their personal log in details or nicknames. An example of the student's page was found in Figure 1, showing the video and the questions. Three Go-lab apps were used to provide students with learning materials, the questionnaire and to collect data: video player, Quiz 2.0, and Quest 2.0. The video player provided video lectures and collects students' interactions with the videos. Quiz 2.0 asked

quiz questions and provided students with correct answers after having collected their initial responses. Quest 2.0 collected and provided responses to the questionnaire.

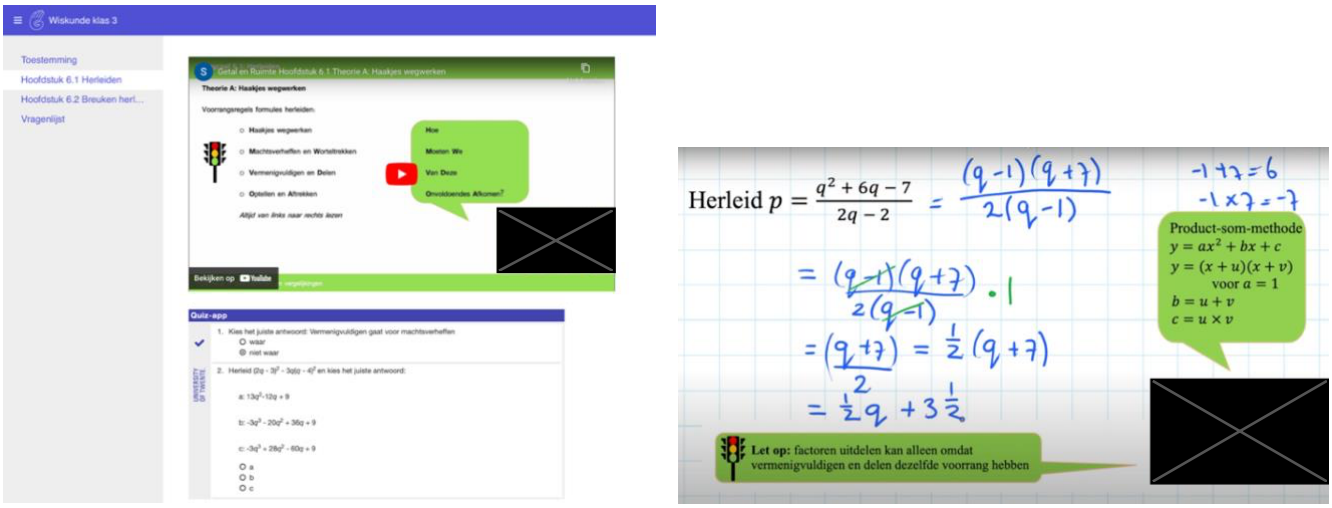
Table 6

Design Engagement Questions based on ICAP Framework

Question	ICAP mode	Reason
I copied the explanation from the video	Active	Active copying of the explanation (Chi & Wylie, 2014, p. 222)
I took notes from the video in my own words	Constructive	Constructive writing notes in own words (Chi & Wylie, 2014, p. 222)
I found it useful to be able to pause the video	Active	Actively manipulating the video (Chi & Wylie, 2014, p. 222)
I found it useful to rewind the video	Actie	Actively manipulating the video (Chi & Wylie, 2014, p. 222)
I found it useful to be able to watch the video at my own pace	Active	Actively manipulating the video (Chi & Wylie, 2014, p. 222)
I now know what is expected of me on the test on sections 6.1 and 6.2	Constructive	Reflecting on what is known or not yet known and knowing what is expected to be known. (Chi & Wylie, 2014, p. 226)
I discussed with fellow students about the explanations of the video	Interactive	Co-creating knowledge by discussing the content (Chi & Wylie, 2014, p. 223)
The questions below the video helped me to better understand the explanation.	Constructive	Self-explaining by the student (Chi & Wylie, 2014, p. 233)
After watching the video, I was able to start with the homework	Constructive	Different topics of the learning materials had to be implemented in order to start with the homework exercises (Chi & Wylie, 2014, p. 226)

Figure 1

Graasp Page for Students and Video Pen Cast



Experiment Notes

Additional qualitative data were collected through observations by the researcher during the lessons and contact with the teachers. Firstly, the structure of the mathematics course was explained by the teacher. After grade 9, students chose different mathematic tracks: mathematics for social studies (wiskunde A) or mathematics for scientific studies (wiskunde B). Chapter 6 contained mathematics for scientific studies and was perceived as difficult by students preferring mathematics for social studies. Secondly, the teacher and the students argued about the level of lesson one versus lesson two. Lesson one was a repetition of theory, whereas lesson two contained new information and required combining background knowledge. Students were struggling with the content of lesson two in both classes, therefore, the teacher and researcher decided to give additional explanations to the class. The third observation described the lack of note-taking by the students. No student wrote lecture notes while watching the video lectures. The teacher explained writing notes is not requested by the teacher during traditional lessons (Teacher, personal communication, April 4, 2023). Finally, during the second lesson in one class, the researcher concluded that students did not take their headphones to class. Therefore, they could not watch the videos at their own pace. Students chose to watch the videos together on one laptop, sharing earbuds. This led to students working together on the exercises as well, resulting in similar answers and no complete data collection of video interactions.

Procedure

This study was conducted between the 1st and 20th of April 2023 at a Technasium secondary school in the eastern part of The Netherlands. The two pre-university classes were taught two times for 60 minutes, the second lesson was given seven or eight days after the first lesson. The teacher received a lesson plan for both lessons. A brief introduction was given by the researcher for five minutes. The students opened their laptops and logged in to Graasp. They gave consent and watched the videos individually using headphones for five minutes. Students answered the quiz questions in Graasp. The researcher was present in the classroom and observed randomly selected students who were watching the video lectures for 20 seconds. She rated their engagement based on the Leuven Scale (Table A1 and Table E1). If students had questions related to the content, they could ask the teacher. Students were reminded to complete the video lectures and quiz questions 15 minutes before the end of class. If the class requested additional examples, the teacher could provide those. When the videos were watched and quiz questions made, students started on their homework for the

remainder of the lecture. The second lecture followed the same format, having the last 10 minutes in class allocated to complete the online questionnaire individually by the students.

Data Analysis

The complete dataset of 39 Technasium students was analyzed. Missing data, due to either missing one of the lessons or other reasons for not answering the complete set of questions were carefully evaluated. Subsequently, only for parts of the analysis that were affected by the missing data, data were excluded from the analysis. This explained the varying number of students over the results section.

Given the nature of the data, which included ordinal data (Likert Scale items) and nominal data that were bounded left and right, non-parametric tests were used since they do not assume normality. The data collected through randomized observation of students, using the Leuven Scale, did not contain missing values. Descriptive statistics were calculated using the software from RStudio. The main objective of the analysis was to determine students' behavioral engagement while watching the videos, as assessed by the Leuven Scale. Statistical analysis was performed to investigate potential differences between the two lessons. The collected data were randomly distributed across classes during both lessons, therefore the samples were treated as independent samples, and the Wilcoxon rank sum test was applied. The responses to the quiz questions were reviewed and scored. The Kruskal-Wallis test determined whether the differences in means were significant among the four levels of engagement. The Wilcoxon signed-rank test was used to verify whether students' scored significantly higher on low engagement levels than on high engagement levels. To check potential differences between the first and second lesson per mode, a non-parametric Wilcoxon signed-rank test was performed, of which the direction was based on the median scores. The Kruskal-Wallis test determined possible significant differences between mean engagement level scores on the online questionnaire. The pairwise comparison Wilcoxon signed-rank test, taking into account the Bonferroni correction, was chosen to check differences between the items per construct.

Results

Description of the Study Variables

This study explored student engagement with flipped classroom learning materials through three methods. Firstly, engagement with video lectures was assessed through Leuven Scale observations. Secondly, the level of active engagement with math content was reviewed

through quiz questions, and finally, student engagement experiences were collected through a questionnaire.

Inferential Statistics on the Leuven Scale

The results of the Leuven Scale showed a low to moderate engagement of the students who were watching the videos ($n = 31$; $M = 2.61$; $SD = 0.99$). Most students sat and watched the videos, but little active involvement was shown. The engagement in the first lesson ($n = 18$; $M = 2.72$; $SD = 0.89$) was higher than the engagement in the second lesson ($n = 13$; $M = 2.46$; $SD = 1.13$). The histograms with the engagement scores in lessons one and two can be found in Appendix H, Figure H1 and Figure H2 respectively. The Wilcoxon rank sum test showed that the median engagement in the first lesson was not significantly different from that of the second lesson ($W = 155$; $p = 0.095$) with $\alpha = 0.05$.

Inferential Statistics on the Quiz Questions

The answers to the quiz questions were evaluated based on the provided answers and coding scheme in the section Engagement Quiz Questions. The results are shown in Figure 2, and the descriptive statistics are found in Table 7. The missing values were removed and the differences between the four ICAP modes were evaluated with the Kruskal-Wallis test ($H(3, n = 288) = 69.6$; $p < 0.001$). The results showed a significant difference between the mean scores of the different ICAP modes. The scores for the lowest engagement levels passive and active of both lessons combined ($Mdn = 4$), were higher than the scores for the highest levels constructive and interactive ($Mdn = 2$). The distribution of the lowest and highest engagement scores can be found in Appendix I, Figure I1 and Figure I2 respectively. The Wilcoxon signed-rank test showed that the median score of the students on the lowest engagement levels was significantly higher than the score on the highest engagement levels ($W^+ = 489.5$; $N = 18$; $z = -4.79$; $P < 0.001$).

The difference per ICAP mode per lesson was tested with the non-parametric Wilcoxon signed-rank test (with $\alpha = 0.05$). Figure 3 and Table 7 showed the results. Passive engagement during the second lesson ($W^+ = 0$; $N = 0$; $z = 0$; $P = 1$) was not higher than the passive engagement in the first lesson. Active engagement during the second lesson was not significantly higher than active engagement during the first lesson ($W^+ = 20$; $N = 7$; $z = -1.04$; $P = 0.149$). Constructive engagement during the second lesson was not significantly higher than constructive engagement during the first lesson ($W^+ = 76$; $N = 18$; $z = 0.50$; $P = 0.690$).

Lastly, the interactive engagement during the second lesson was significantly higher than the interactive engagement during the first lesson ($W^+ = 144$; $N = 17$; $z = -3.61$; $P < 0.001$).

Figure 2

Scores per Engagement Level of Lessons 1 and 2

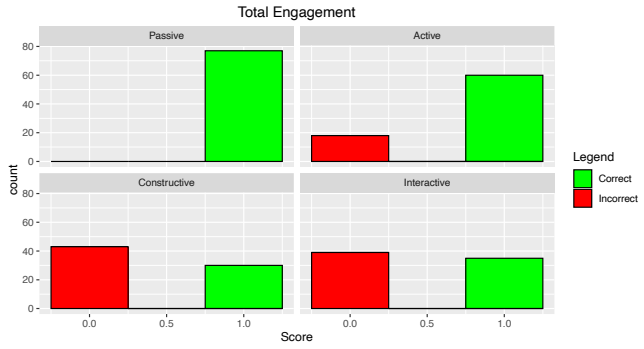


Table 7

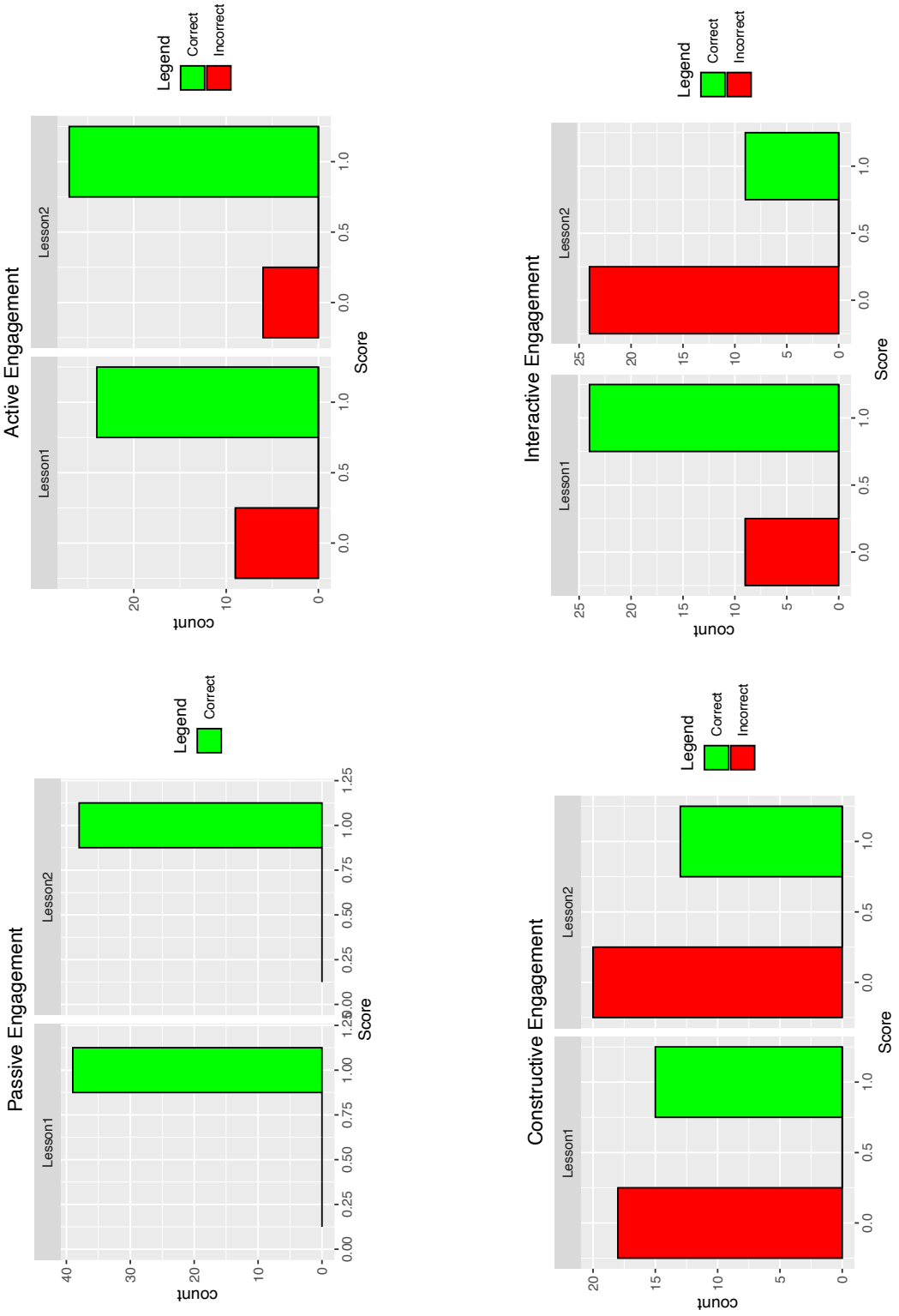
Descriptive Statistics ICAP Questions

	Lesson 1				Lesson 2				Combined			
	n	NA[1]	%[2]	Mdn	n	NA[1]	%[2]	Mdn	n	NA[1]	%[2]	Mdn
Passive	39	0	100.00	1	39	1	100.00	1	78	1	100.00	1
Active	39	0	74.40	1	39	0	79.50	1	78	0	76.90	1
Constructive	39	5	44.10	0	29	0	38.50	0	78	5	41.10	0
Interactive	39	4	71.40	1	39	0	25.60	0	78	4	47.30	0

[1] Missing values
[2] Correct percentage without missing values

Figure 3

Scores Passive, Active, Constructive, and Interactive Engagement



Inferential Statistics on Questionnaire

The online questionnaire sought the reflection of students on their engagement and covers active, constructive, and interactive engagement. The descriptive statistics of the engagement questionnaire were found in Table 8. The Kruskal-Wallis test showed that the means of active engagement ($M = 3.15$), constructive engagement ($M = 2.21$), and interactive engagement ($M = 3.36$), were significantly different ($H(2, n = 396) = 51.7$; $p < 0.001$). The pairwise comparison was done using the Wilcoxon signed-rank test and was adjusted for Bonferroni ($\alpha = 0.05/3 = 0.017$) to check where the differences occurred. The results showed that constructive engagement was significantly different from active ($W^+ = 7616.0$; $N = 132$; $z = -5.74$; $P < 0.001$) and interactive ($W^+ = 4872.0$; $N = 132$; $z = -6.16$; $P < 0.001$) engagement, having a significantly lower mean. The active and interactive engagement were not significantly different ($W^+ = 12269.5$; $N = 132$; $z = -1.26$; $P = 0.021$).

The constructs of active and constructive engagement consisted of four items each. The Kruskal-Wallis test showed a significant difference between the four active questions ($H(3, n = 132) = 25.3$; $p < 0.001$), which was also seen in Table 8 and Figure 4 where question 1.1 had a lower score on active engagement than questions 1.3, 1.4, and 1.5. The pairwise comparison Wilcoxon signed-rank test, adjusted for Bonferroni ($\alpha = 0.05/4 = 0.0125$) confirmed a significant difference between questions 1.1 and 1.3 or 1.4 or 1.5 ($W^+ = 236$; $N = 33$; $z = -3.66$; $P < 0.001$), and no significant difference between the 1.3, 1.4, and 1.5 (see Table J1).

The results for the constructive engagement showed a difference in means as well (see Table 8). The Kruskal-Wallis test confirmed a significant difference between the mean scores of the constructive engagement questions ($H(3, n = 132) = 39.1$; $p < 0.001$). The results of the pairwise comparison Wilcoxon signed-rank test, adjusted for Bonferroni ($\alpha = 0.05/4 = 0.0125$) were found in Table J2). The mean score for question 1.2 ($M = 1.24$) was significantly different (lower) than the mean scores of questions 1.6 ($M = 2.39$), 1.8 ($M = 2.60$), and 1.9 ($M = 2.79$). The latter three means were not significantly different.

Table 8

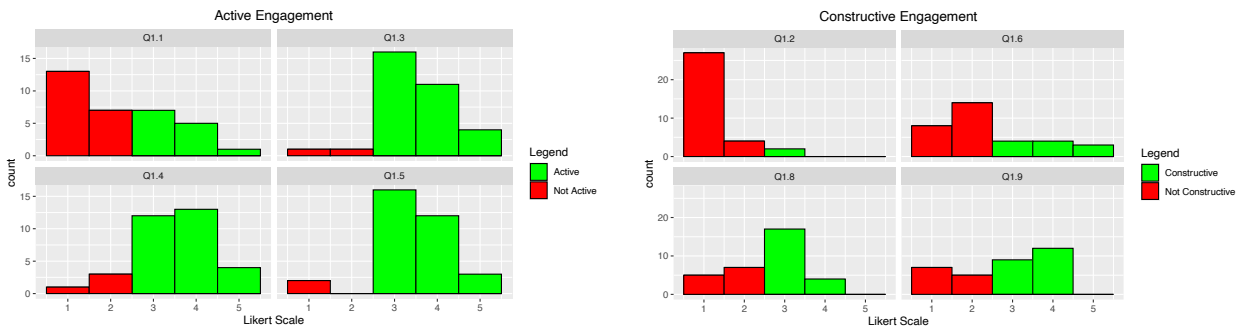
Descriptive Statistics Reflection of Students' Engagement

		M	SD	W	P
Active	Q1.1+Q1.3+Q1.4+Q1.5	3.15	1.12	0.88	<0.001
	Q1.1	2.21	1.21		
	Q1.3	3.48	0.87		
	Q1.4	3.48	0.94		
	Q1.5	3.42	0.90		
Constructive	Q1.2+Q1.6+Q1.8+Q1.9	2.21	1.14	0.86	<0.001
	Q1.2	1.24	0.56		
	Q1.6	2.39	1.24		
	Q1.8	2.60	0.90		
	Q1.9	2.79	1.17		
Interactive	Q1.7	3.31	1.45	0.87	<0.001

Figure 4

Results from Active and Constructive Reflection per Question

(a) Active Engagement (b) Constructive Engagement



Discussion

The current study is designed to explore the engagement of Dutch students in a 9th-grade pre-university Technasium school in flipped classroom mathematics video lectures. Students' engagement is studied by observing their behavior, examining acquired skills and knowledge, and analyzing their reflections on their engagement with video lectures.

Students' Behavioral Engagement

The expectation of high behavioral engagement, level 4 or 5 on the Leuven Scale, is not verified by the results of this study. Observations display that students show a low to moderate level of behavioral engagement, level 2 to 3 while watching video lectures. They are not fully concentrated, show limited motivation watching the videos, and do not take notes. Students might not show a high level of engagement as they are probably not used to actively engaging with videos. Previous experiences with watching entertainment videos in their off-time could lead to passive behavior. This might influence their reaction to instructional videos, resulting in a passive to moderate engagement level.

In addition, students are not used to note-taking during their traditional mathematics lectures as this is not expected nor recommended by their teacher (see Experiment Notes). Students do not see the need for taking notes, even though video lectures contain dense information, where note-taking could help with processing information on a deeper level (Jansen et al., 2017). Therefore, it might be that teaching the importance and skills of note-taking for flipped classroom video lectures could foster behavioral engagement. Little research is available on students' behavioral engagement during secondary school mathematics classes. Hafen et al. (2012) describe observations of engagement in the classrooms of grades nine to twelve and found a passive level of engagement. This study contributes to those findings by describing similar results of behavioral engagement during video lectures watched during class.

Students' Engagement with Quiz Questions

Engagement with the learning content confirms that students score high on the passive and active questions (above 75%), and lower on the constructive and interactive questions (40-50%). Students are moderately to highly engaged with the learning content. However, students might have different strategies for answering questions. For example, the reason to answer might be based on their knowledge and skills, guessing, or working with a classmate. In addition, the moment of answering might be during the video lecture, after completing all exercises, or not answering at all. High-engagement questions require deep-level thinking and

combining previously learned knowledge with new content (Chi & Wylie, 2014). However, such questions may be too difficult and may lead to incorrect answers and disengagement (Laevers et al., 2016). Students giving a wrong answer could either be highly engaged and actively searching for the right answer, or not engaged at all by guessing an answer. Despite this limitation, the results represent the engagement level of these students in this school. Moreover, utilizing quiz questions leads to two practical implications. Firstly, the online learning environment allows for providing feedback to the students with additional learning materials selected by the teacher and for students to monitor their learning. Secondly, the teacher is able to monitor students' results and might use them to determine the learning activities for the in-class time. Knowing the exact needs, knowledge gaps, and lacking skills of the students allows for differentiating instructions based on individual students' needs (Lo et al., 2017). However, future research is needed to determine the best moment for collecting data through questions, since the moment of answering was not recorded. On top of that, students were encouraged to answer the questions at their own pace and time, meaning before or after watching the video, and before or after practicing with homework exercises. This might influence the scoring rates as some students may have practiced and studied more than others before answering the questions. Quiz questions during out-of-class activities and before in-class time should be explored before data-driven teaching might be implemented.

Students' Reflection on Engagement

The reflection of students on their level of engagement gives a subjective insight into their experiences with the learning materials. They score moderate on active and interactive engagement and low on constructive engagement. First, it is concluded that students score significantly lower on the questions regarding their active and constructive note-taking, compared to the other three active and constructive questions, as seen in Figure 4. This is in line with the findings of the behavioral engagement as described in the section Students' Behavioral Engagement, confirming the recommendation to inform and teach students about note-taking during video lectures. The low to moderate scores on constructive engagement gives some insight into the results of the engagement with learning materials. It shows their somewhat negative experiences with the videos and questions as they might have expected to learn constructively by watching videos passively. In addition, van Alten (2019) questions the correctness of students' own assessment, especially when it comes to assessing their skills in relation to the learning goal. This should also be taken into account when evaluating their positive reflections on their interactive engagement. Students are asked to watch the videos

during in-class time to allow for observations of students' behavior which consequently results in direct discussions with their classmates. That might lead to this highly interactive engagement, which was only possible during in-class time. Taking this limitation into account, it can be concluded that videos and questions are useful instruments to engage the students at a passive, active, and constructive level of engagement. Constructive discussions with peers, leading to interactive engagement may be an important aspect and probably the main focus of the in-class time as suggested by Bhagat et al. (2016) as well. A follow-up study is recommended to research the design and engagement of in-class time activities in secondary schools to accomplish a full study of the engagement, design, and effect of the flipped classroom experiences by secondary school students, taking into account the different levels and age groups (van Alten et al., 2019). Finally, another limitation of this study is the separate recordings of the behavior and quiz questions. Due to the protocol of the school, it is not possible to link random individual behavioral engagement with responses to quiz questions or reflection scores. For future research, it would be recommended to collect individual scores, since linking these provides insight into the overall engagement per student. Linking individual engagement scores and researching student engagement with watching videos out of class as suggested by the flipped classroom approach, might raise the ecological validity of this study.

Overall it can be concluded that students consider themselves actively, somewhat constructively, and interactively engaged during video lectures in the flipped classroom approach.

Conclusion

The current study provides a clear insight into the engagement of 9th-grade pre-university Technasium students in this Dutch secondary school. Observations of their behavioral engagement show low to moderate engagement. Responses to quiz questions indicate students' very active engagement. Lastly, students express their engagement to be constructive. These results highlight the need for teachers to encourage note-taking during video lectures to improve students' engagement. Educators can utilize quiz questions for data-driven differentiated in-class activities, recommended by this study. The findings in this study offer insight into their students' engagement with mathematics video lectures and provide design suggestions to optimize student engagement in the future.

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Appendix A

Leuven Scale

Table A1

The Scale for Involvement (Laevers et al., 2005)

THE SCALE FOR INVOLVEMENT		
LEVEL	INVOLVEMENT	EXAMPLES
1	**Extremely low**	The child hardly shows any activity: • no concentration: staring, daydreaming; • an absent, passive attitude; • no goal-oriented activity, aimless actions, not producing anything; • no signs of exploration and interest; • not taking anything in, no mental activity.
2	**Low**	The child shows some degree of activity but which is often interrupted: • limited concentration: looks away during the activity, fiddles, dreams; • is easily distracted; • action only leads to limited results.
3	**Moderate**	The child is busy the whole time, but without real concentration: • routine actions, attention is superficial; • is not absorbed in the activity, activities are short lived; • limited motivation, no real dedication, does not feel challenged; • the child does not gain deep-level experiences; • does not use his/her capabilities to full extent; • the activity does not address the child's imagination.
4	**High**	There are clear signs of involvement, but these are not always present to their full extent: • the child is engaged in the activity without interruption; • most of the time there is real concentration, but during some brief moments the attention is more superficial; • the child feels challenged, there is a certain degree of motivation; • the child's capabilities and its imagination to a certain extent are addressed in the activity.
5	**Extremely high**	During the episode of observation the child is continuously engaged in the activity and completely absorbed in it: • is absolutely focussed, concentrated without interruption; • is highly motivated, feels strongly appealed by the activity, perseveres; • even strong stimuli cannot distract him/her; • is alert, has attention for details, shows precision; • its mental activity and experience are intense; • the child constantly addresses all its capabilities: imagination and mental capacity are in top gear; • obviously enjoys being engrossed in the activity.

Appendix B
Consent Permission Parents

Beste ouders/verzorgers,

In samenwerking met de school zal er een onderzoek plaatsvinden naar de wiskundelessen van uw zoon/dochter. Het doel van het onderzoek is om de betrokkenheid van leerlingen te onderzoeken wanneer zij videolessen kijken.
Als onderdeel van een nieuw lesprogramma zullen de leerlingen tijdens de reguliere wiskundeles video's kijken met wiskunde uitleg. De inhoud van de video's zijn gemaakt in overeenstemming met de school en de wiskundedocent, waarmee de kwaliteit van de les gewaarborgd is. De uitleg die in de video's gegeven wordt is dezelfde uitleg die de docent zou gaan geven tijdens deze les, maar dan vooraf opgenomen. De klas zal geobserveerd worden waarbij gekeken wordt hoe de leerlingen met het lesmateriaal bezig zijn. Uw zoon/dochter zal enkele wiskundevragen beantwoorden na het kijken van de video, en in de tweede les zal er een vragenlijst worden ingevuld met vragen over wat de leerlingen van de les vonden.

Alle gegevens die verzameld worden zijn anoniem en niet herleidbaar naar een individuele leerling. De gegevens worden behandeld volgens de Nederlandse Gedragscode Wetenschapsbeoefening, opgesteld door de vereniging van universiteiten VSNU. De gegevens worden in een beveiligde server opgeslagen op de Universiteit van Twente en na 10 jaar vernietigd.
Alle antwoorden blijven vertrouwelijk en zullen alleen gezien worden door de onderzoeker (Maaike van der Louw) en haar begeleider van de Universiteit van Twente (Hannie Gijlers).

Indien u bezwaar heeft kunt u voor 3 april 2023 contact opnemen met Maaike van der Louw of Hannie Gijlers. U kunt hen een mail sturen waarin u vermeld dat uw zoon/dochter niet meedoet met het onderzoek, u hoeft hiervoor geen reden te vermelden.
Uw zoon/dochter zal wel aanwezig zijn en meedoen in de les, maar er zullen geen gegevens opslagen worden. De video's worden dan via een ander programma bekeken.
Mocht u uw zoon/dochter op een later moment willen terugtrekken uit het onderzoek, dan kan dat door een mail te sturen en zullen de gegevens verwijderd worden. Dit kan tot uiterlijk 16 april 2023.

Wilt u informatie over de uitkomsten van dit onderzoek, dan kunt u na afloop van de onderzoeksperiode contact opnemen met de wiskundedocent van uw zoon/dochter. Zij zal beschikken over een samenvatting van de onderzoeksresultaten.

Met vriendelijke groet,

Maaike van der Louw
[redacted]

Hannie Gijlers
[redacted]

UNIVERSITY OF TWENTE.

Appendix C

Consent Permission Students

Vragenlijst app

UNIVERSITY OF TWENTE.

1. Hoi! *

Jij bent uitgenodigd om mee te doen aan een onderzoek naar de wiskundelessen door videolessen te bekijken en een paar vragen te beantwoorden. De titel van dit onderzoek is:

Technasium students in high school: A study on the engagement in flipped classroom video lectures.

Het doel van deze studie is te onderzoeken wat leerlingen op een Technasium school nodig hebben in de wiskundeles. Het kijken van de video's en het invullen van de vragen doe je tijdens de les. Je bent er dus 2x 60 minuten mee bezig en leert de lesstof die je voor deze hoofdstukken moet leren. De data die verzameld wordt, gaat gebruikt worden om te kijken wat je van de les vond.

Je deelname is vrijwillig en je mag op elk moment tijdens de les aangeven als je niet wil dat er data verzameld wordt van jou. Je mag vragen overslaan als je ze echt niet in wilt vullen.

Omdat de les is gemaakt met je wiskunde docent over de onderwerpen uit het boek, geloven we dat er geen risico is om mee te doen. Je leert de lesstof die je anders ook zou krijgen, maar nu op een andere manier. De vragen worden anoniem ingevuld en zijn niet achteraf te koppelen aan jou. Jouw antwoorden blijven ook vertrouwelijk en zullen alleen gezien worden door mij (Maaike) en mijn begeleider van de Universiteit van Twente: Hannie Gijlers. Om risico's zo klein mogelijk te maken wordt de data veilig opgeslagen op een beveiligde server van de Universiteit van Twente. De data is anoniem gemaakt doordat de inloggegevens die je gekregen hebt volledig random zijn en nergens gekoppeld zijn aan jouw naam of klas.

Voor vragen kun je contact opnemen met:

Maaike van der Louw
[redacted]

Hannie Gijlers
[redacted]

Ik heb de tekst hierboven gelezen, begrijp wat er staat en geef toestemming om de data te verzamelen die er deze en volgende les verzameld gaan worden voor dit onderzoek.

- ☐ ja
- ☐ nee

Appendix D

Scripts Video Lectures

Table D1

Hoofdstuk 6.1 Theorie A

Beeld	Tekst
PowerPoint slide (PPT) vooruitblik video	Welkom bij deze video over hoofdstuk 6, paragraaf 1, Theorie A. In deze video gaan we kijken naar haakjes herleiden.
PPT schrijven Ik klein	Voordat we gaan herleiden, kijken we eerst nog even naar de voorrangsregels: Haakjes Machtverheffen & Wortels trekken Vermenigvuldigen & Delen Optellen & Aftrekken En als ze dezelfde voorrang hebben zoals machten en wortels, dan is de regel van links naar rechts. Als ezelsbruggetje kun je denken aan: Hoe Moeten We Van Die Onvoldoendes Afkomen?
	Maak nu opdracht 1 onder deze video
OneNote: Vraag in beeld. Ruimte om som 2a uit te schrijven	Herleid $2(d+7)^2$ We gaan eerst de formule omschrijven, zodat we de haakjes weg kunnen werken, dus dan krijgen we $2(d+7)*(d+7)$, dit merkwaardige product wordt $2(d^2+14d+49)$, en om de laatste haakjes weg te werken vermenigvuldigen we alles keer 2 $2d^2+28\,d + 98$
PPT: terugblik op de video, huiswerk opdrachten	In deze video heb je geleerd hoe je haakjes weg moet werken met hulp van de voorrangsregels. Maak nu vraag 2 onder deze video en maak de opdrachten 2 tot en met 5 uit je boek. Succes!
Vraag 1.1:	Vermenigvuldigen gaat voor machtsverheffen - Waar - Niet waar
Vraag 1.2:	Herleid $(2q - 3)^2 - 3q(q - 4)^2$ en kies het juiste antwoord: a: $13q^2-12q + 9$ b: $-3q^3 - 20q^2 + 36q + 9$ c: $-3q^3 + 28q^2 - 60q + 9$ ○ a ○ b ○ c

Table D2

Hoofdstuk 6.1 Theorie B

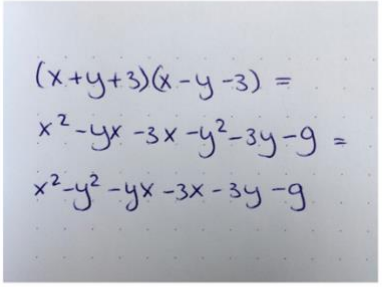
PPT: vooruitblik video	Welkom bij deze video over hoofdstuk 6, paragraaf 6.1, Theorie B. We gaan het hebben over producten met tweetermen en drietermen.
PPT: zie tekst hiernaast	Een tweeterm is een som die bestaat uit twee termen. Een drieterm is een som die bestaat uit, je raad het al, drie termen.
	We kunnen het product van een tweeterm en een drieterm herleiden, door alle termen met elkaar te vermenigvuldigen.
OneNote: voorbeeld en ruimte om het voorbeeld uit te schrijven	Laten we samen het volgende voorbeeld herleiden: (x+3)*(x+y+1) Eerst vermenigvuldigen we de eerste term van tweeterm met alle termen van de drieterm: x*x wordt x2; x*y wordt xy; x*1 wordt x Dan vermenigvuldigen we de tweede term van de tweeterm met alle termen van de drieterm: 3*x wordt 3x; 3*y wordt 3y; 3*1 wordt 3 Nu kijken we of we de formule nog korter kunnen schrijven: x^2 blijft x^2; xy blijft xy; x+3x wordt 4x; 3y blijft 3y; En 3 blijft 3
PPT: terugblik op de inhoud van deze video en huiswerk	We hebben in deze video samen gekeken hoe we rekenen met producten van tweetermen en drietermen. Maak de vragen onder de video en als huiswerk maak je opdracht 6-8 uit je boek. Succes
Vraag 1.3	Maak de volgende berekening compleet: Herleid $(3x + 2)^3$ = *Let op: machten schrijf je zo: x^2 = x^2 en x^3 = x^3* *^ typ je met shift+6* = (____)(____)^2 = (____)(____) = _____ = _____
Vraag 1.4	Je vriend heeft som 8a gemaakt, maar hij komt er niet uit. Dit is zijn berekening:  $(x+y+3)(x-y-3) =$ $x^2-yx-3x-y^2-3y-9 =$ $x^2-y^2-yx-3x-3y-9$ Welke tips zou jij hem geven zodat hij er wel uit kan komen?

Table D3

Hoofdstuk 6.2 Theorie A

PPT : vooruitblik video	Welkom bij deze video over **hoofdstuk 6. Paragraaf 6.2.** We gaan kijken naar **theorie A** over het vereenvoudigen van breuken.
PPT : inhoud tekst hiernaast	Als we breuken herleiden, willen we ze zo klein en overzichtelijk mogelijk schrijven. Pq/5 wordt dan 1/5 pq Bij breuken met tweetermen en drietermen, kijken we welke factoren we eruit kunnen halen.
OneNote: som en ruimte om te schrijven. Herinnering product-som-methode in beeld	Laten we kijken naar een voorbeeld: Herleid $p=(q^2+6q-7) / (2q-2)$ De teller kunnen we herschrijven volgens de product-som-methode: herinner je dat $y=ax^2+bx+c$ kunt schrijven als $y=(x+u)(x+v)$, waarbij de som van u en v b moet worden en het product van u en v moet c worden? Als we kijken naar onze teller, dan weten we dat -1+7=6 en -1*7=-7 Dus nu krijgen we $q^2+6q-7 = (q-1)(q+7)$ De noemer kunnen we herschrijven door de 2 buiten de haakjes te halen: $(2q-2) = 2(q-1)$ Dan krijgen we $p = (q-1)(q+7)/2(q-1)$ Nu kunnen we dezelfde factoren uitdelen, namelijk (q-1)/(q-1) is 1, en vereenvoudigen we de breuk tot ½*(q+7) Als laatst werken we de haakjes weg en krijgen we 1/2q+3 1/2
PPT : Terugblik op de video	In deze video hebben we gekeken hoe we breuken kunnen vereenvoudigen door factoren uit de teller en de noemer te halen. Maak nu de opdrachten onder deze video en daarna opdracht 12-16 uit je boek. Succes!
Vraag 2.1	Herleid $\frac{12abc}{-4ac} =$ a. $\frac{12abc}{-4ac} = -3b$ b. $\frac{12abc}{-4ac} = \frac{12b}{-4}$ c. $\frac{12abc}{-4ac} = 3b$
Vraag 2.2	Het voorbeeld uit de video is hetzelfde als voorbeeld b uit het boek. We hebben $p = \frac{q^2+6q-7}{2q-2}$ herleid tot $p = \frac{1}{2}q + 3\frac{1}{2}$. Licht toe dat deze herleiding niet klopt voor $q = 1$.

Table D4

Hoofdstuk 6.2 Theorie B

PPT: vooruitblik video	Welkom bij hoofdstuk 6, paragraaf 6.2. In deze video gaan we kijken naar rekenen met breuken.
PPT: vooruitblik video	In deze video gaan we kijken naar het optellen, aftrekken, vermenigvuldigen en delen van gelijknamige en niet-gelijknamige breuken.
PPT: steekwoorden van tekst	Gelijknamige breuken hebben dezelfde noemer. Bij het optellen en aftrekken van gelijknamige breuken blijft de noemer staan. We rekenen dan alleen met de teller, bijvoorbeeld
OneNote: som en ruimte om te schrijven	10b / (b+3) – 6b/(b+3) = 4b /(b+3)
PPT: steekwoorden van de tekst	Niet-gelijknamige breuken hebben niet dezelfde noemer. Voor het optellen en aftrekken moet je ze eerst gelijknamig maken.
OneNote: som en ruimte voor tekst	10/(b+3) + 5/b = 10b/b(b+3) + 5(b+3)/b(b+3) = Uitschrijven: 5b+15/b(b+3) 10b+5b+15 / b(b+3)= 15b+15 / b(b+3) Wat je onder vermenigvuldigd heb moet je boven ook mee vermenigvuldigen om de breuk gelijk te houden.
PPT: steekwoorden van de tekst	Als we breuken vermenigvuldigen, maakt het niet uit of ze gelijknamig zijn of niet. We doen namelijk: Breuk *breuk = teller*teller/noemer*noemer
OneNote: som en ruimte om te schrijven	Dus a/b *c/d = ac/bd
PPT: steekwoorden tekst	Als we breuken delen door breuken, volgen we de regel: ‘delen door een breuk is hetzelfde als vermenigvuldigen met het omgekeerde van die breuk’ dus :
OneNote: som en ruimte om te schrijven	x/y / v/z = x/y * z/v = xz/yv
PPT: terugblik en huiswerk	In het boek staan nog meer uitgewerkte voorbeelden. In deze video hebben we gekeken naar het optellen, aftrekken, vermenigvuldigen en delen van gelijknamige en niet-gelijknamige breuken. Maak nu de opdrachten onder de video en maak opdracht 18 en 19 uit het boek. Succes!
Vraag 2.3	Delen door een breuk is hetzelfde als vermenigvuldigen met het omgekeerde van die breuk. - Waar - Niet waar
Vraag 2.4	Herleid $\frac{a}{3} - 2a$ en kies het juiste antwoord: a. $-\frac{5a}{3}$ b. $-1\frac{2}{3}a$ c. $-\frac{a}{3}$ d. $\frac{2}{3}a^2$

Appendix E

Leuven Scale Recordings

Table E1

Leuven Scale Observation Form

Student number	1 Extremely low	2 Low	3 Moderate	4 High	5 Extremely high

Appendix F

Questionnaire Dutch

Vragenlijst app

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1. De volgende vragen gaan over wat *jij deed* tijdens het kijken naar de video.

	helemaal mee oneens	oneens	neutraal	eens	helemaal mee eens
Ik kopieerde de uitleg van de video	○	○	○	○	○
Ik maakte aantekeningen van de video in eigen woorden	○	○	○	○	○
Ik vond het fijn de video op pauze te kunnen zetten	○	○	○	○	○
Ik vond het fijn de video terug te kunnen kijken	○	○	○	○	○
Ik vond het fijn de video in mijn eigen tempo te bekijken	○	○	○	○	○
Ik weet nu wat er van mij verwacht wordt op de toets over paragraaf 6.1 en 6.2	○	○	○	○	○
Ik heb met medeleerlingen gediscussieerd over uitleg van de video	○	○	○	○	○
De vragen onder de video hielpen mij de uitleg beter te begrijpen	○	○	○	○	○
Na het kijken van de video kon ik aan de slag met het huiswerk	○	○	○	○	○

De volgende vragen gaan over de vormgeving van de video:

2. De introductie van elke video vond ik:
   - ☐ niet nuttig
   - ☐ neutraal
   - ☐ nuttig

3. De uitleg in de video was:
   - ☐ onduidelijk
   - ☐ neutraal
   - ☐ duidelijk

4. De afsluiting met terugblik op de video vond ik:
   - ☐ overbodig
   - ☐ neutraal
   - ☐ fijn

5. De vragen onder de video waren:
   - ☐ niet nuttig
   - ☐ neutraal
   - ☐ nuttig

6. De lengte van de video's was:
   - ☐ te lang
   - ☐ precies goed
   - ☐ te kort

7. De spreeksnelheid in de video was:
   - ☐ te langzaam
   - ☐ precies goed
   - ☐ te snel

8. De geschreven uitleg in de video hielp mij met het leren
   - ☐ oneens
   - ☐ neutraal
   - ☐ eens

9. Dat ik de docent kon zien spreken in de video vond ik:
   - ☐ overbodig
   - ☐ neutraal
   - ☐ prettig

Als laatste nog een paar vragen over jouw achtergrond:

10. Mijn gender is:
    - ○ man
    - ○ vrouw
    - ○ anders

11. Wat is je leeftijd?

    Antwoord:

12. Wat sta je nu voor wiskunde?

    (schrijf jouw cijfer met een komma ertussen, bijvoorbeeld 7,0)

    Antwoord:

13. Doe jij Technasium?
    - ○ ja
    - ○ nee

14. Als je Technasium doet, wat sta je nu voor O&O?

    (schrijf jouw cijfer met een komma ertussen, bijvoorbeeld 7,0)

    (Als je geen Technasium doet, mag je deze vraag overslaan)

    Antwoord:

Dank je wel voor je inzet!

Je mag nu de laptop afsluiten en verder gaan met je opdrachten.

Appendix G

Questionnaire English

1. **The following questions are about what *you did* while watching the video.**

	Totally disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I copied the explanation from the video					
I took notes from the video in my own words					
I found it useful to be able to pause the video					
I found it useful to rewind the video					
I found it useful to be able to watch the video at my own pace					
I now know what is expected of me on the test on sections 6.1 and 6.2					
I discussed with fellow students about the explanations of the video					
The questions below the video helped me to better understand the explanation.					
After watching the video, I was able to start with the homework					

The following questions are about the design of the video:

2. I found the introduction in each video:
    - Not useful
    - Neutral
    - Useful
3. The explanation in the video was:
    - Unclear
    - Neutral
    - Clear
4. The closing of the video with a recap was:
    - Unnecessary
    - Neutral
    - Convenient
5. The questions below the video were:
    - Not useful
    - Neutral
    - Useful

6. The length of the videos was:
    - Too long
    - Just right
    - Too short
7. The speaking rate in the video was:
    - Too slow
    - Just right
    - Too fast
8. The written explanation in the video helped me learn
    - Disagree
    - Neutral
    - Agree
9. That I could see the teacher speaking in the video was:
    - Unnecessary
    - Neutral
    - Pleasant

Finally, a few questions about your background:

10. My gender is:
    - Male
    - Female
    - Different

11. What is your age?
    Answer:_____

12. What is your current grade for the mathematics course?
    (Please write your grade, separated by a comma: 7,0)
    Answer:_____

13. Are you following the Technasium program?
    - Yes
    - No

14. If you are in the Technasium program, what is your current grade for O&O (Research and Design)?
    (Please write your grade, separated by a comma: 7,0)
    (If you are not in Technasium, you can skip this question)
    Answer:_____

Thank you for your efforts!
You can close the laptop and continue with your homework.

Appendix H

Leuven Scale of Involvement Scores

Figure H1

Results Leuven Scale of Involvement Lesson 1

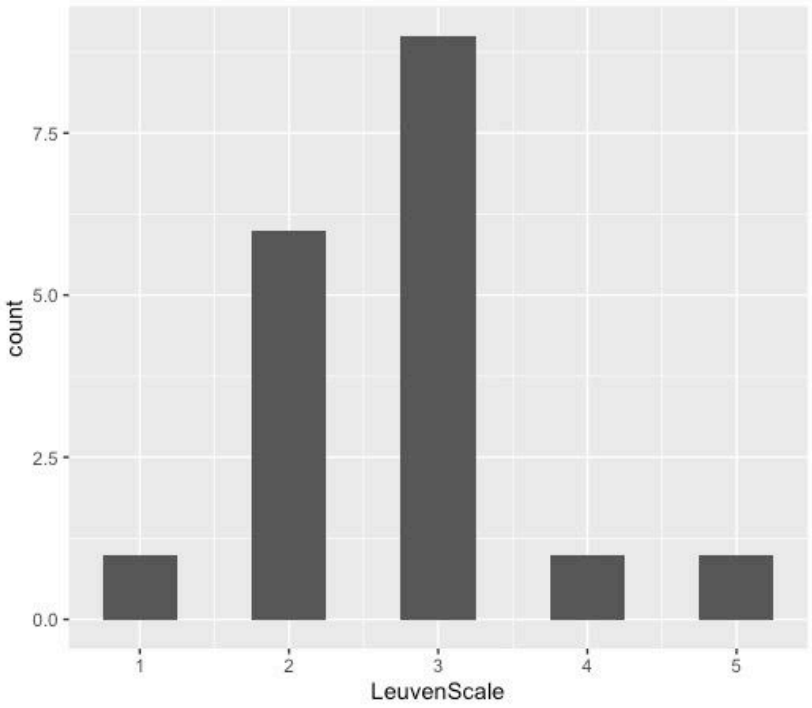
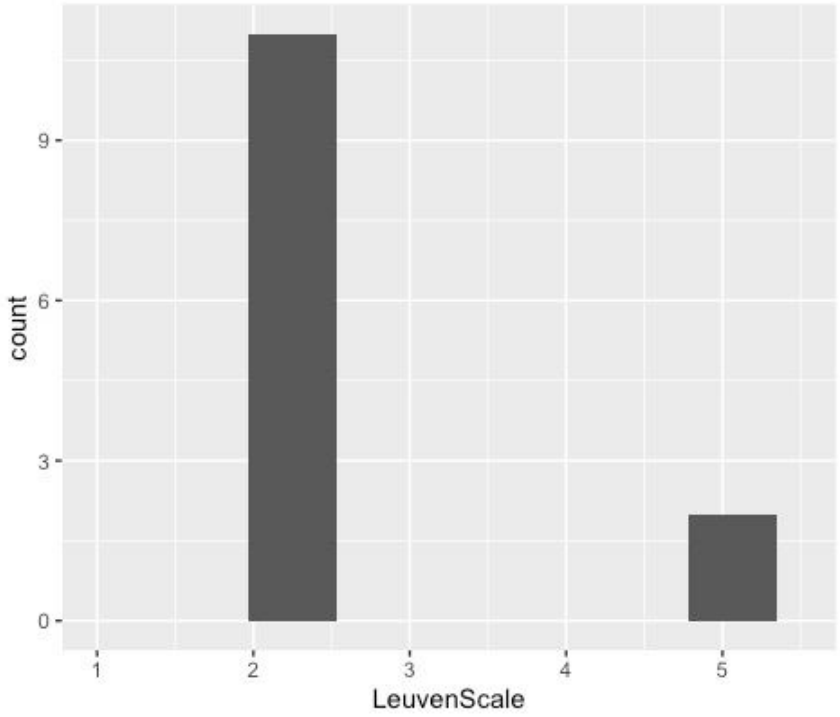


Figure H2

Results Leuven Scale of Involvement Lesson 2



Appendix I

Low and High Engagement Scores

Figure I1

Results Scores on Lowest Engagement Lessons One and Two

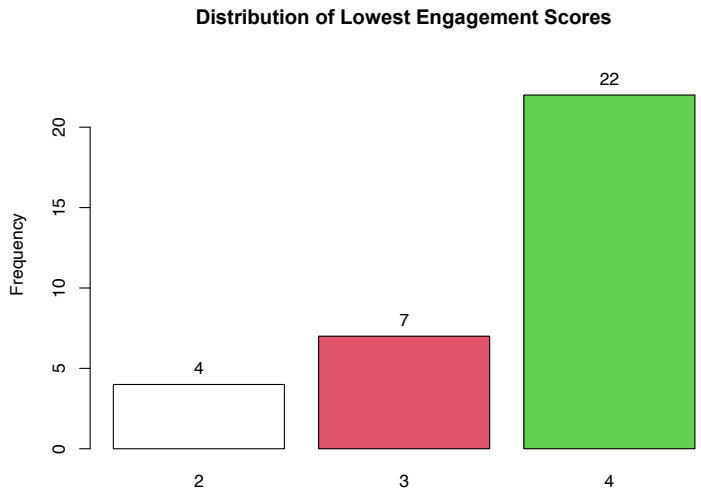
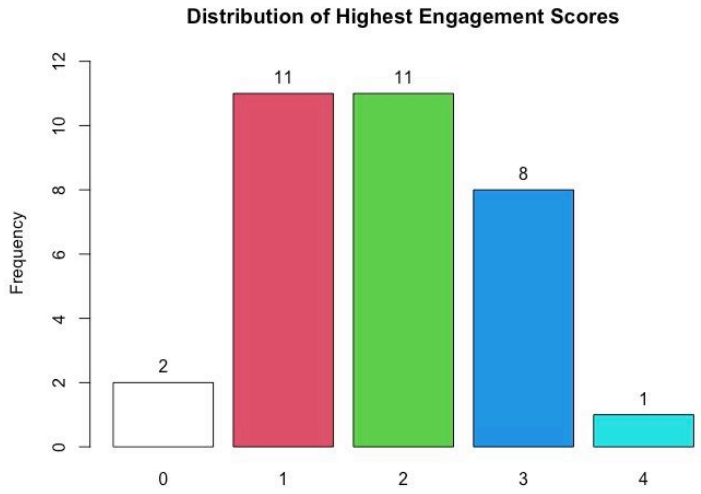


Figure I2

Results Scores on Highest Engagement Lessons One and Two



Appendix J

Results Pairwise Comparisons Active and Constructive Engagement

Table J1

Results Pairwise Comparisons using Wilcoxon Signed-Rank Test Active Engagement

Group 1	Group 2	n1	n2	W+	p adj	z
Q1.1	Q1.3	33	33	236	<0.001	-3.66
Q1.1	Q1.4	33	33	238	<0.001	-3.61
Q1.1	Q1.5	33	33	248	<0.001	-3.48
Q1.3	Q1.4	33	33	534	1	0
Q1.3	Q1.5	33	33	553	1	0
Q1.4	Q1.5	33	33	565	1	0

Table J2

Results Pairwise Comparisons using Wilcoxon Signed-Rank Test Constructive Engagement

Group 1	Group 2	n1	n2	W+	p adj	z
Q1.2	Q1.6	33	33	216	<0.001	-4.23
Q1.2	Q1.8	33	33	142	<0.001	-5.24
Q1.2	Q1.9	33	33	166	<0.001	-4.92
Q1.6	Q1.8	33	33	444	1	0
Q1.6	Q1.9	33	33	434	0.876	-0.16
Q1.8	Q1.9	33	33	472	1	0