The Effects of Two Different Types of Video Clip Sequencing on Knowledge Acquisition in a Flipped Learning Course

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Abstract

Flipped classrooms approaches (FCA) are more and more used in todays' universities. One key component of FCA is presenting online instructional video clips. Even though the design of these video instructions is important for knowledge construction and transfer, teachers have little guidance in how to sequence them: topic by topic (atomistic) or from generic to specific (holistic). The purpose of this study is to examine the differential effects of atomistic and holistic sequenced video clips on knowledge acquisition in a flipped learning course. Using a quasi-experimental design, 98 students of two cohorts received information in how to design learning materials based on the 4C/ID model for seven weeks. One cohort received atomistic designed web lectures, the other holistic designed web lectures. An online modified card sorting task measured their knowledge acquisition. A mixed MANOVA and mixed ANOVAs showed the differential effects of the conditions over time. Results show that the holistic and atomistic hardly differ in the knowledge acquisition process in a flipped course. Teachers can use the strategy they prefer and find convenient, because students' knowledge acquisition process does not primarily favour one over the other.

The Effects of Two Different Types of Video Clip Sequencing on Knowledge Acquisition in a Flipped Learning Course

The past decade flipped classroom approaches (FCA) increased in popularity across educational fields and are widely applied in universities (Bredow et al., 2021; Turan & Cimen, 2020; van Alten et al., 2019). Moreover, with the emergence of the COVID-19 pandemic, where universities switched to online education and smaller class sizes, the numbers of FCA only grew (Campillo-Ferrer et al., 2021). That seems to be a good transition, because compared to traditional education, FCA increases learning outcome (Bredow et al., 2021; Låg & Sæle, 2019; Lo & Hew, 2017; Cheng et al., 2019; Strelan et al., 2020; van Alten et al., 2019; Vitta & Al-Horrie, 2020) and intra-/interpersonal skills (Akçayır & Akçayır, 2018; Bredow et al., 2021). Some studies also indicate positive effects on student satisfaction (Akçayır & Akçayır, 2018; Bredow et al., 2021), but research is not unanimous (Låg & Sæle, 2019; van Alten et al., 2019). FCA is defined as students preparing with instructional video material before class, and class time is used to apply and engage with the instructional material (Bredow et al., 2021). Even though definitions of FCA differ based on the use of technology, the vast majority of studies to FCA include online instructional videos, indicating that video instructions are a key aspect of FCA (van Alten et al., 2019; Vitta & Al-Horrie, 2020). So, in a flipped designed course students watch multiple video clips in which learning content is presented, understanding that content is needed for active participation during the in-class activities. However, some teachers are unfamiliar how to design effective FCA and video instructions (Lo & Hew, 2017; Rosman et al., 2016).

The design of video instructions affects how students construct the information in their brain and influences transfer. Learners have to connect the presented pieces of information as well as the relations between them, to their prior knowledge (Merrill, 2007a; Reigeluth, 2007; van Merriënboer & Kirschner, 2018). Multiple design elements influence this knowledge acquisition process (e.g., presentation and methods), sequencing is seen as an important one (Doroudi et al., 2016; Ou et al., 2019; Renkel & Atkinson 2003; Ritter et al., 2007). The sequencing design element is concerned with the order learning content is presented to the students. Because multiple video instructions are provided in FCA, sequencing design issues can focus on either macro level or micro level. Micro level issues are concerned with decisions within a single video. For example, if information in the video first activates prior knowledge, then show a demonstration, stimulate applying the information, and finally encourage the student to integrate the new knowledge into their daily life (Merrill, 2007b). Macro level issues, on the other hand, are engaged with decisions between the multiple videos. It refers to how all the different video clips in the course are lined relative to each other to stimulate effective learning acquisition. For example, if the order of the videos is from generic to specific, by topic, chronological, or steps-by-step in a procedure (Patten et al., 1986). Unfortunately, little research provides insight in which macro sequencing strategy is most effective in the process of knowledge acquisition.

Therefore, this study focused on macro level sequencing strategies in a flipped learning course. As described, teachers increasingly have to design instructional video clips to convey and explain learning content in their flipped learning courses. Thus, the question how teachers should sequence their video clips to facilitate effective knowledge acquisition is more vital than ever. Online instructional video clips can take multiple forms, this study concentrated on web lectures. This study examined how web lectures should be sequenced for effective knowledge acquisition. The results of this study can close the gap in knowledge and guide teachers' instructional video design. When teachers implement the proper instructional video sequence, students can more effectively construct and acquire knowledge which can have a positive effect on students' transfer.

Theoretical Framework

Sequencing decisions

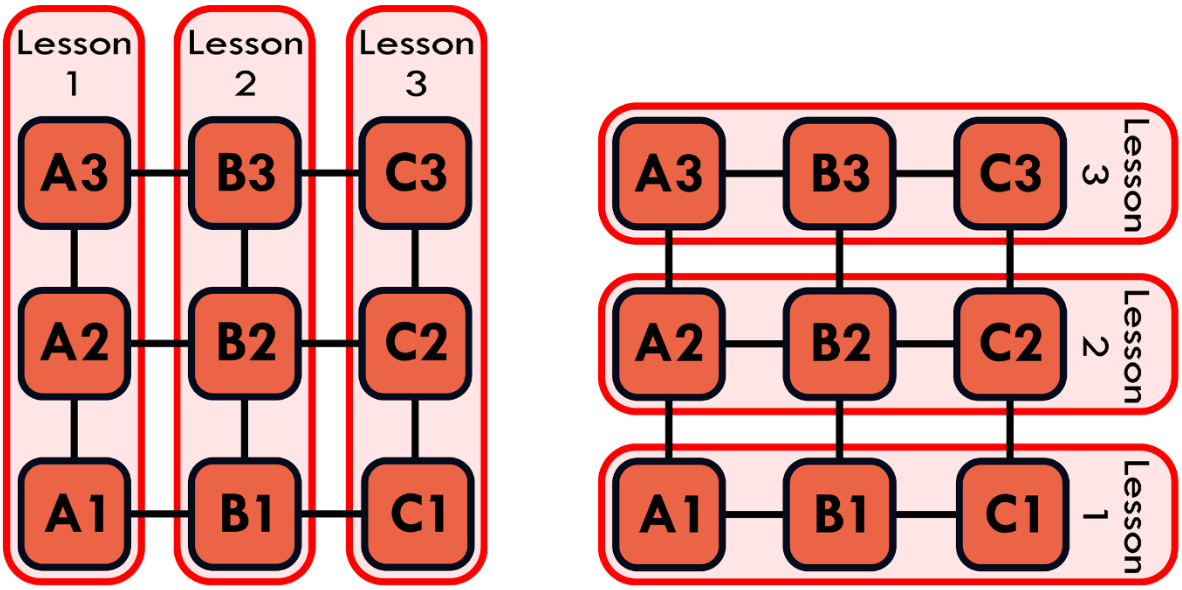
Sequencing decisions deal with how to group and order instructional content (Reigeluth, 2007). They are choices about (a) how information needs to be broken up into chunks that do not exceed learners cognitive load capacity, (b) how the chunks need to be ordered, and (c) how to sequence the content within a chunk. These choices affect the quality of the instruction. The impact of sequencing depends upon two factors: the strength of the relationship among the topics and the size of the course of instruction. Sequencing is important when there is a strong relationship among the topics of the course. When the topics requires more than about an hour to learn, sequencing is likely to begin make a significant difference (Reigeluth, 2007).

Sequencing strategies

As reviewed by Patten et al. (1986), sequencing strategies go back to the 1960's. When several topics need to be taught, two popular basic patterns of sequencing can be applied that are fundamentally different: atomistic and holistic (Frerejean et al., 2019; Reigeluth, 2007; van Merriënboer & Kirschner, 2018). The atomistic strategy orders its' videos on topic. Every lesson a new topic is addressed with all its' complexity levels. For example, in lesson 1 'topic A' is explained with complexity level 1, level 2 and level 3. In lesson 2 'topic B' is explained with complexity level 1 to level 3. Finally, in lesson 3 'topic C' is described with all its' complexity levels. Lessons with a holistic strategy orders its' videos on complexity level. All topics are described in every lesson, but the complexity level increases over time. So, in the first lesson 'topic A', 'topic B', and 'topic C' are all presented on complexity level 1. In lesson 2, the three topics are all explained on complexity level 2. Lastly, in lesson 3 'topic A', 'topic B', and 'topic C' are reviewed on complexity level 3. Figure 1 shows schematically the atomistic and holistic design. The two strategies will be explained next.

Figure 1

Schematic Diagram of Atomistic and Holistic Sequencing Design



Note. The letters indicate a topic, the numbers the complexity level.

Atomistic Sequencing Designs

Atomistic designs, also called topical or part-task designs, present domain-specific information in small pieces with the same complexity level (van Merriënboer & Kirschner, 2018). The advantage of atomistic sequencing is that learners can concentrate on one topic for in-depth learning without frequently skipping to new topics. Also, learning materials all can be used in one timeframe, rather than scattered over multiple schedules (Reigeluth, 2007). Atomistic approaches are effective to prevent cognitive overload, but they would not be effective for learning complex tasks as complex skills are characterized by highly integrated sets of learning objectives (Spector & Anderson, 2000; van Merriënboer et al., 2003, Wickens et al, 2013). Critics argue that atomistic sequencing leads to fragmentated instruction (*framing*), the inability to integrate the learning (*compartmentalization*), and poor application of knowledge in new situations (*transfer*) (Lim et al., 2008; van Merriënboer & Kester, 2008).

Learners do not gain the perception of the whole task domain until the end of the course. During the course, the earlier topics can be forgotten. However, including an overview, review, and synthesis can compensate for these deficiencies (Reigeluth, 2007).

Holistic Sequencing Designs

Holistic designs, also called spiral, generic-to-specific, or whole-task designs, first present simplified information and then more complex information. The presentation of instruction confronts learners with the whole task and is focused on transfer of the learning content (van Merriënboer & Kester, 2008; van Merriënboer & Kirschner, 2018). The holistic strategy would lead to a gradual increase during the course (van Merriënboer & Kirschner, 2018). The advantage of holistic sequencing is the built-in synthesis and review. Similar aspects of various topics are learned closer to each other in time, and the topics are periodically reviewed. Therefore, the relationship between topics might be learned more easily and more in-depth (Reigeluth, 2007). Furthermore, research from Lim et al. (2008) indicated that whole-task instructions result in higher performance outcome than part-task instructions. One disadvantage of the holistic approach is that the switching between topics can disrupt leaners' thought development. Besides, switching may disrupt efficient management of learning materials because they need to be moved along with the progress (Reigeluth, 2007). A final disadvantage is that a holistic design can leads to a higher workload for teachers (i.e., provision of adequate feedback and regular update of study materials) (Wopereis et al., 2016). All and all, it is not clear from literature which sequencing strategy teachers should implement in their flipped course.

Present study

Much has been written about the potential value of the holistic and atomistic approaches (e.g., Frerejean et al., 2019; Merrill, 2002, 2007b; van Merriënboer, 2007).

Nevertheless, research comparing the sequencing structure between different video clips (macro level) is limited, specifically when focused on FCA. Furthermore, little research compares and provide insight in the process of knowledge acquisition in holistic and atomistic approaches. The lack in macro level sequencing and knowledge acquisition research makes it is unclear how knowledge acquisition proceeds in an atomistic and holistic flipped course. In sum, online video instruction is increasingly implemented in today's classes, but teachers do not know how to sequence their instructional videos which might impair students' knowledge acquisition process. Therefore, this study examined how teachers should sequence their web lectures in a flipped learning course, resulting in the research question: *What are the differential effects of atomistic sequenced web lectures and holistic sequenced web lectures on the knowledge acquisition process in a flipped learning course?*

Hypothesized (H1) is that there is a difference in knowledge acquisition between the two conditions. Some research (e.g., Reigeluth, 2007; Lim et al., 2008; van Merriënboer & Kester, 2008) indicate that the holistic condition would lead to higher knowledge acquisition. Therefore, one could expect that the knowledge acquisition trajectory would be better for the holistic strategy than for the atomistic strategy. But, based on atomistic research (e.g., Reigeluth, 2007), one could suppose that atomistic sequenced web lectures lead to more knowledge on specific topics and thus to better knowledge acquisition. Due to this ambiguity in literature, which strategy leads to better knowledge acquisition is not defined in this hypothesis.

The second hypothesis is focused on in-depth knowledge. It is hypothesized (H2) that both strategies increase in in-depth knowledge on a topic and do not differ in in-depth knowledge after the atomistic condition discussed the topic in class. This hypothesis is based on the research of Reigeluth (2007), stating that students receiving atomistic sequenced web lectures would only view the whole task domain in the end of the course and only learn topics after they are discussed. In other words, students who receive atomistic sequenced video instructions first have low in-depth knowledge in the topic, but the students' knowledge level would increase quickly after the topic is presented. This argument would indicate a significant increase and better in-depth knowledge for the atomistic strategy (when focused on the moment students just received the information). However, Reigeluth (2007) also states that the periodical review in the holistic strategy leads to better in-depth knowledge on a topic. Furthermore, the holistic strategy would lead to a gradually increase during the course (van Merriënboer & Kirschner, 2018). Due to the equivalency in arguments, it is expected both strategies increase and lead to the same level of in-depth knowledge after the atomistic strategy have discussed the topic.

Methods

Research Design

The differential effects of atomistic and holistic web lectures were examined using a quasi-experimental, mixed-model design with sequencing strategy (atomistic versus holistic) as independent variable and knowledge acquisition as dependent variable. For the between-subject factor, students from two cohorts with the same curriculum followed a flipped learning course. Only the sequence of web lectures differed. Both conditions received the exact same web lectures, but in a different week during the course. The atomistic condition received weekly videos serialized based on topic. The holistic condition received every week videos that were arranged based on complexity level. The atomistic condition were students who followed the flipped course in 2017-2018. Students who attended the course in 2018-2019 received holistic videoclip instructions.

For the within-subject factor, the students participated in a weekly online modified card sorting task. The task was identical every week and appealed to the domain-specific knowledge level of the students. Answer options consisted of four separate components (specific topics) taught during the course. The four components together covered the core concept. The four separate components were *learning tasks*, *supportive information*, *procedural information*, and *part task practice*. The core concept was *4C/ID*. The score one got provided insight in the knowledge acquisition process of the specific topics and core concept.

The first hypothesis, knowledge acquisition differs between the two conditions, focused on the interaction between sequencing strategy and knowledge acquisition. So, without the segmentation of the separate components. Therefore, the dependent variable was the score on 4C/ID. The second hypothesis, atomistic sequencing leads to a significant increase in in-dept knowledge after the topic is discussed in class, focused on the interaction between sequencing strategy, knowledge acquisition, and separate components. Thus, the dependent variable to test the second hypothesis was the score on learning tasks, supportive information, procedural information, and part task practice.

Participants

By a convenience sample, a total of 394 students in the academic years 2017-2018 and 2018-2019 participated in this study. Participation was voluntary, one could always stop without providing a reason. Via informed consent, participants indicated if their data could be used for research practices. The university's Ethics Committee approved this study. The respondents participated in this study without academic or financial compensation.

After chronological deleting respondents who did not sign the informed consent (120 persons), provide demographic information (8 persons), did not participated during all measurements (163 persons), and receive a grade on the exam (6 persons) or assignment (1 persons) the final dataset resulted in 96 participants (M_{age} = 24.19, SD_{age} = 5.91). Forty-eight participants in the atomistic condition (M_{age} = 23.25, SD_{age} = 4.66) and 48 participants in the holistic condition (M_{age} = 25.13, SD_{age} = 6.87). Table 1 shows all demographic information.

Table 1

Demographic Information Participants

Baseline characteristic	Atomistic		Holistic		Total	
	n	%	*n*	%	*n*	%
Gender						
Male	11	22.9	9	18.8	20	20.8
Female	37	77.1	39	81.3	76	79.2
Study programme						
Bachelor	14	29.2	17	35.4	31	32.3
Premaster	34	70.8	29	60.4	63	65.6
Other	0	0	2	4.2	2	2.1
Study type						
Part-time	8	16.7	12	25.0	20	20.8
Full-time	40	83.3	36	75.0	76	79.2
Prior education						
Pre-University	17	35.4	19	39.6	36	37.5
Applied Sciences	28	58.3	21	43.8	49	51.0
Other	3	6.3	8	16.7	11	11.5
Years of work experience						
None	22	45.8	22	45.8	44	45.8
<1	12	25.0	6	12.0	18	18.8
1-5	10	20.8	12	25.0	22	22.9
5-10	4	8.3	3	6.3	7	7.3
>10	0	0	5	10.4	5	5.2
Study progress						
Behind schedule	2	4.2	6	12.5	8	8.3
On schedule	46	95.8	39	81.3	85	88.5
In frond of schedule	0	0	3	6.3	3	3.1
Motivation level: Educational sciences						
Low	0	0	0	0	0	0
Somewhat low	0	0	0	0	0	0
Not low, not high	5	10.4	3	6.3	8	8.3
Somewhat high	26	54.2	18	37.5	44	45.8
High	17	35.4	27	56.3	44	45.8
Motivation level: DLSa						
Low	0	0	0	0	0	0
Somewhat low	0	0	1	2.1	1	1.0
Not low, not high	6	12.5	3	6.3	9	9.4
Somewhat high	27	56.3	25	52.1	52	54.2
High	15	31.3	19	39.6	34	35.4

Materials

Flipped Classroom Course

The participants enrolled in the course *Designing Learning Situations – advanced* (DLSa), which is part of the bachelor curriculum Educational Sciences of Utrecht University. In DLSa, students learn how to design learning situations and learning material based on the four component instructional design (4C/ID) model of Van Merriënboer and Kirschner (2018). 4C/ID provide educational designers a framework for designing effective courses and trainings. The four components of the model are learning tasks, supportive information, procedural information, and part task practice. Learning tasks refers to assignments a student does to learn desired actions. Supportive information provides the students with information they need to successfully complete nonrecurrent aspects of the learning tasks. Procedural information is information for learning the routine aspects of learning tasks. Part task practices are additional activities a learner can do to train routine aspects of a skill.

The course had a flipped classroom design: a series of web lectures were provided one week before a classroom tutorial meeting. During the meeting, students had to apply the weeks’ information in classroom assignments. Reading literature and watching instructional videos was necessary to actively engage in the tutorial meeting. DLSa consisted of eight weeks, in the first seven weeks instructional content was provided. Table 2 presents how the course content is distributed for each sequencing group. Every tutorial meeting started with an online card sorting task. Afterwards, the students did activities with the learning content of that week. Throughout the course, students worked on a group assignment for which they were graded. The course ended with an exam.

Table 2

Content Distribution over the Seven Weeks for Both Conditions

Course week	Atomistic	Holistic
Week 1	Introduction to course	Instructional design models and designing instruction (level 1)
Week 2	Design models/ designing instruction	Four components, assessment, evaluation (level 1)
Week 3	Learning tasks, task classes, performance assessments	Instructional design models and designing instruction (level 2)
Week 4	Supportive information	Four components, assessment, evaluation (level 2)
Week 5	Procedural information	Instructional design models and designing instruction (level 3)
Week 6	Part task practices and domain-general skills	Instructional design models and designing instruction (level 3)
Week 7	Assessment programs and evaluation	Four components, assessment, evaluation (level 3)

Online Card Sorting Task

A series of identical online modified card sorting tasks measured the knowledge acquisition during the course. The task let students sort a term (card) to one of four given categories, namely the four components of the 4C/ID model. The task required student to think of the term's meaning and how that term is related to one of the categories. If the students had the appropriate level of domain-specific knowledge, they could assign terms to the correct category (Jonassen et al., 1993). The card sorting task was online designed and is shown in Appendix A.

First, the students answered four questions about what literature they read, how much time it took, which web lectures they saw, and how much time they worked on the group assignment. Then, the students were presented with the online card sorting task: 44 terms which had to be assigned individually to the component learning tasks, supportive information, procedural information, or part task practice. A term could be assigned by checking a box. Students were asked only to assign it when they knew it with certainty, otherwise they were asked to indicate they did not know the answer. The terms were alphabetically ordered. Correct answers were distributed over the components as followed: 16 learning tasks, 10 supportive information, 12 procedural information, and 6 part task practices.

To ensure reliability and validity, the task was created by the course coordinator, who is expert in 4C/ID. The test was based on the card sorting technique described by Jonassen et al. (1993). Literature shows card sorting tasks are robust in distinguishing knowledge acquisition between groups (Bissonnette et al., 2017; Smith et al., 2013).

Procedure

Students enrolled in DLSa and were introduced with general information about the course. Each week, the students had to (a) read assigned literature, (b) watch a series of web lectures, (c) participate in a tutorial meeting and complete the knowledge acquisition assignment, (d) work on a group assignment, and (e) learn for the exam. Students were free to decide when they would work on the activities. Only the tutorial meetings were set at a specific date and time in the week.

Each tutorial meeting started with the online cards sorting assignment. In the first week, students were provided with an information letter which stated the goal, the impact of the assignment on the tutorial meetings, which data is collected, and how data is processed. Also, students were asked to sign an informed consent. Next, with a link to an online survey, students have filled in their name and other demographic information, which then let them to start the online card sorting task. At the top, information about how the assignment worked and could be used in the students' learning process was stated. When the students ended the assignment, the tutorial meeting started.

Data Analysis

Demographic and motivational factors of the two conditions will be analysed with a Chi-square test to review if the conditions are comparable. Next, the number of correct sorted terms for the four separate components will be calculated per participant per week. Also, the separate scores will be summed to indicate the score on 4C/ID per participant per week. Then, in order to answer the research question, a mixed design MANOVA will run with sequencing conditions as independent variable and the scores on the card sorting task as dependent variable. The dependent variable consisted of seven measuring points, and four separate component scores. Afterwards, five mixed design ANOVAs will be performed with sequencing conditions as independent variable and the scores on the card sorting task as dependent variable. One mixed design ANOVA will use the 4C/ID score, the other four use the score students got on the separate components.

All analyses will be done in IBM SPSS Statistics. Assumptions are checked for all analyses and show no reason for non-parametrical testing. A detailed description is shown in Appendix B. When sphericity is not assumed, the Greenhouse-Geisser correction will be used, unless the epsilon would be over $\varepsilon = .75$, then the Huynh-Feldt correction will be applied (Field, 2018). A level of $\alpha = .05$ will be used in all analyses to indicate significance. Bonferroni correction will be applied for pairwise comparison (Harris, 1975). Because of the equal sample size and the violations of assumptions, the Pillai-Bartlett trace will be used for the Multivariate Tests to indicate significance (Field, 2018). A partial eta square of $\eta^2 = .01$ will indicate a small effect, above $\eta^2 =.06$ a medium effect, and above $\eta^2 = .14$ a large size effect (Cohen, 1992).

Results

This research aimed to examine how teachers should sequence their web lectures in a flipped learning course. Differential effects of two sequencing strategies were compared. Students received atomistic or holistic sequenced web lectures during a flipped learning course. The students participated in a series of online card sorting tasks, which provided insight into their knowledge acquisition process with a focus on four separate specific topics and the core concept of the course. Before the results of these analyses, the demographics of the conditions were examined.

Demographic Information

The two conditions were compared on demographic information to analyse statistical differences that could influence the result on the next analyses. The descriptive statistics of the demographics are shown in Table 1. The Chi-square analysis showed the conditions did not statistically differed on age ($X^2(19) = 19.631$, $p = .417$), gender ($X^2(1) = 0.253$, $p = .615$), study program ($X^2(2) = 2.687$, $p = .261$), study type ($X^2(1) = 1.011$, $p = .315$), prior education ($X^2(2) = 3.384$, $p = .184$), work experience ($X^2(4) = 7.325$, $p = .120$), study progress ($X^2(2) = 5.576$, $p = .062$), motivation for the study Education Sciences ($X^2(2) = 4.227$, $p = .121$), and motivation for the course DLSa ($X^2(3) = 2.548$, $p = .467$). The two conditions do not significantly differ based on demographics and therefore cannot be an explanation for differential results in next analyses.

Knowledge Acquisition

Multivariate Tests

A mixed MANOVA was run because this research had multiple dependent variables; the score on the learning tasks component, supportive information component, procedural information component, and part task practice component. Taken these four dependent variables together would indicate a fifth variable: the score on the core concept of the course

(4C/ID). A mixed MANOVA analyses the whole conceptual model. If all five dependent variables would be analysed independently, the Type 1 error would inflate and relationships between outcome variables would be ignored. Only when the mixed MANOVA provide significant results on the multivariate test statistic, multiple mixed ANOVAs with Bonferroni adjustments can be run without an increased Type 1 error (Bock, 1975; Field, 2018; Harris, 1975).

The multivariate test indicated a significant main effect of the separate components ($F(3) = 165.934$, $p < .001$, $\eta^2 = .844$), a significant main effect of time ($F(6) = 68.047$, $p < .001$, $\eta^2 = .821$), a significant interaction effect between time and sequencing strategy ($F(6) = 4.037$, $p = .001$, $\eta^2 = .214$), a significant interaction effect between the separate components and time ($F(18) = 16.942$, $p < .001$, $\eta^2 = .798$), and a significant interaction effect between the separate components, time and sequencing strategy ($F(18) = 4.108$, $p < .001$, $\eta^2 = .490$). All with a large effect size. The test showed a non-significant interaction effect of the components and the sequencing strategy ($F(3) = 1.156$, $p = .331$).

A significant multivariate test statistic would indicate a significant effect between the variables, but the nature of this effect is not clear from the statistic. Hence, when there is a significant multivariate test statistic, a univariate test has to be conducted to determine the nature of the results (Field, 2018). Therefore, only the interaction effect between the separate components and sequencing strategy is not further inspected. All other effects are reviewed.

Univariate Test

Totally, six univariate test statistics have been monitored. A main effect of sequencing strategy is not analysed by the multivariate test but is reviewed in the univariate test. The test of between subject effect tested if the mean score of the atomistic condition ($M = 3.205$) and of the holistic condition ($M = 3.280$) differed significantly. The test showed no main effect of sequencing strategy (*F*(1) = 0.063, $p = .803$). Meaning, the atomistic condition does not statistically differ on average test performance than the holistic sequenced video instruction condition. Students in both conditions scored on the card sorting task on average the same.

The within subject effect test analysed a main effect of the components. So, testing if the mean scores on four components differed regardless the condition. The results show a significant main effect of the components (*F*(2.337) = 217.615, $p < .001$, $\eta^2 = .698$), with a large effect size. Meaning, the mean total scores displayed in Table 3 in the column 'Total' differ statistically. Pairwise comparisons show all these mean scores differ significantly from each other. These results are not surprising due to the difference in quantity of correct answers.

Then, a main effect of time was inspected. Time is the factor name for the within subject variable that indicate the difference in the card sorting task score between the weeks. A significant main effect of time would indicate that students' scores would have increased (or decreased) during the time of the course. For the first week the average score was M = 0.990, in week 2 M = 1.865, week 3 M = 2.560, week 4 M = 2.883, week 5 M = 3.927, week 6 M = 4.891, and week 7 M = 5.581. The analysis showed a significant main effect of time (*F*(3.497) = 179.513, $p < .001$, $\eta^2 = .656$). The effect size is large. Meaning, the average score between the weeks differed significantly during the course. Pairwise comparison shows all weeks differed significantly from each other, except the difference between week 3 and week 4. Thus, students acquired more domain-specific knowledge on the 4C/ID model during the course, except during week 4.

Table 3

Average Scores on Separate Components

Component	Atomistic		Holistic		Total	
	M	*SD*	*M*	*SD*	*M*	*SD*
Learning tasks	5.152	2.114	5.086	2.671	5.119	2.396
Supportive information	3.214	1.522	3.107	1.791	3.161	1.654
Procedural information	3.699	1.458	3.866	2.216	3.783	1.868
Part task practice	0.753	0.747	1.060	0.889	0.906	0.831

Next, the interaction effect between the components and time was checked. This effect would indicate that, regardless of the sequencing strategy, students' score on the separate topics would increase during the course. The test showed a significant interaction effect between the components and time ($F(11.836) = 30.101$, $p < .001$, $\eta^2 = .243$), with a large effect size. Indicating that the mean scores (shown in Table 4 in the column 'Total') on the separate components during the course differed substantially.

Then, which is important for the first hypothesis, an effect of sequencing strategy on time is reviewed. The test compared the scores on the card sorting task without separation of the four topics during the course. In other words, it tested if students' knowledge on 4C/ID increased during the course and at a time differed between the atomistic and holistic condition. Table 4 show the mean scores for the strategies per week in the '4C/ID' rows. Results show an effect of video sequencing strategy on time ($F(3.497) = 3.440$, $p = .012$, $\eta^2 = .035$). The effect size is small. The two sequencing strategies differ in acquisition of knowledge during the course. Meaning, either the holistic condition or the atomistic condition scored higher than the other at some moment during the course. The later section will provide insight in which strategy and at which moment the scores differed significantly.

Table 4

Average Number of Correct Sorted Terms per Condition per Week

Course week	Component	Atomistic		Holistic		Total	
		M	*SD*	*M*	*SD*	*M*	*SD*
Week 1	Learning tasks	1.48	1.750	1.48	1.516	1.48	1.629
	Supportive information	0.73	1.233	0.98	1.391	0.85	1.314
	Procedural information	1.25	1.480	1.40	1.440	1.32	1.455
	Part task practice	0.33	0.630	0.27	0.676	0.30	.651
	4C/ID	3.79	3.935	4.12	3.977	3.96	3.939
Week 2	Learning tasks	2.88	2.120	2.96	2.269	2.92	2.184
	Supportive information	1.46	1.762	1.63	1.931	1.54	1.841
	Procedural information	2.38	1.985	2.58	2.395	2.48	2.191
	Part task practice	0.67	0.996	0.38	0.841	0.52	.929
	4C/ID	7.38	5.081	7.54	5.642	7.46	5.341
Week 3	Learning tasks	4.75	2.884	3.77	3.116	4.26	3.027
	Supportive information	1.52	1.968	2.81	2.598	2.17	2.383
	Procedural information	2.52	1.968	3.88	3.008	3.20	2.618
	Part task practice	0.40	0.707	0.83	1.173	0.61	.988
	4C/ID	9.19	5.618	11.29	7.771	10.24	6.827
Week 4	Learning tasks	5.79	3.255	5.67	4.102	5.73	3.683
	Supportive information	1.65	2.119	2.98	2.480	2.31	2.390
	Procedural information	2.15	1.856	3.58	2.608	2.86	2.365
	Part task practice	0.46	0.771	0.79	1.202	0.62	1.018
	4C/ID	10.04	5.543	13.02	8.549	11.53	7.321
Week 5	Learning tasks	6.67	3.144	6.08	3.999	6.37	3.590
	Supportive information	5.10	2.991	3.96	2.932	4.53	3.002
	Procedural information	3.31	2.627	4.40	3.369	3.85	3.054
	Part task practice	0.63	1.084	1.27	1.673	0.95	1.439
	4C/ID	15.71	6.751	15.71	10.279	19.56	8.650
Week 6	Learning tasks	6.87	3.064	7.19	4.185	7.03	3.652
	Supportive information	5.79	2.736	4.35	2.764	5.07	2.829
	Procedural information	7.06	2.956	5.00	3.464	6.03	3.367
	Part task practice	1.06	1.643	1.79	1.833	1.43	1.770
	4C/ID	20.79	7.702	18.33	10.018	19.56	8.973
Week 7	Learning tasks	7.63	2.870	8.46	4.371	8.04	3.702
	Supportive information	6.25	2.347	5.04	2.888	5.65	2.687
	Procedural information	7.23	2.660	6.23	3.502	6.73	3.134
	Part task practice	1.73	1.685	2.08	2.102	1.91	1.903
	4C/ID	22.83	7.177	21.81	10.758	22.32	9.110

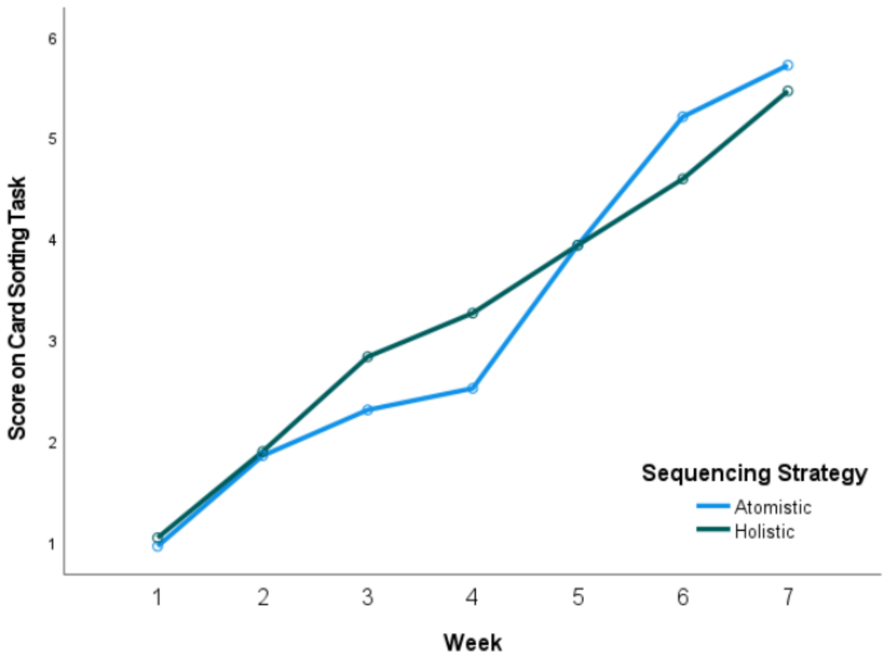
The last univariate test statistic provided the results for the second hypothesis. The analysis tested if there is an increase in score on the separate components somewhere during the course and if the two sequencing strategies differed. The separate component scores for all seven weeks, shown in Table 4, for the atomistic and holistic conditions have been compared. The result shows a significant interaction effect between the components, sequencing conditions, and time ($F(11.836) = 8.768$, $p < .001$, $\eta^2 = .085$), with a medium effect size. Implying, during the course there is a difference between the atomistic and holistic condition in the knowledge acquisition for at least one of the four topics. The next section shows in which week, which strategy a higher score had on which individual components.

Knowledge Acquisition Difference in Strategy

Hypothesis 1 is focused on the interaction effect between sequencing condition and time. As there is a significant interaction between the two strategies and the knowledge acquisition process, a mixed ANOVA was run to analyse which strategy at what moment during the course scored higher on the card sorting task. Figure 2 shows the knowledge acquisition in 4C/ID over the seven weeks for both conditions. The sequencing strategies only statistically differed in week 4 ($t(1) = -2.026$, $p = .046$, $\eta^2 = .042$). The effect size is small. The holistic condition scored 2.979 points higher compared to the atomistic condition. Comparing the other scores per week showed no statistical difference between conditions. Exploratory research in Appendix C shows if the different trajectory influenced the learning outcome. Appendix D shows exploratory research into the knowledge acquisition trajectory, providing a more detailed view on the increase in knowledge between the strategies.

Figure 2

Card Sorting Task Score Atomistic and Holistic Condition on 4C/ID



Knowledge Acquisition Difference in In-depth Knowledge

Hypothesis 2 is focused on in the interaction effect between sequencing condition and time for each component individually. Because the interaction effect between the components, sequencing conditions, and time was significant, four separate ANOVAs were run to analyse the increase in scores on the separate components. The topic learning tasks was discussed in week 1 in the atomistic condition, so a significant increase of the score on the card sorting task regarding the topic is expected in week 2. The topic supportive information was discussed in week 4 in the atomistic condition, so a significant increase of the score regarding the topic is expected in week 5. The component procedural information was reviewed in the atomistic condition a week after supportive information. Therefore, the score on the card sorting task regarding procedural information is expected to grow significantly in week 6.

Finally, the topic part task practice was discussed in week 6 in the atomistic condition, thus a significant increase of the score on the card sorting task is expected in week 7.

Firstly, for a correct overview of the analysis, the main effect of time for each component individually is described. The mixed ANOVAs tested for all the four topics if the scores increased significantly during the course. The analyses showed a main effect of time when focused on the learning tasks score ($F(4.469) = 106.715$, $p < .001$, $\eta^2 = .532$), supportive information score ($F(5.089) = 104.121$, $p < .001$, $\eta^2 = .536$), procedural information score ($F(3.741) = 94.258$, $p < .001$, $\eta^2 = .501$), and part task practice score ($F(3.811) = 26.166$, $p < .001$, $\eta^2 = .218$). All four effect sizes are large. Implying, the students sorted more terms correctly in the end of the course for every component then in the beginning.

Secondly, the interaction effect between sequencing strategy and the increase in knowledge during the course for each component was analysed. For each component, the increase in knowledge in the expected week is reviewed, as well as the difference in score between the two conditions. Figure 3 shows the average score on learning tasks for both conditions during the course. As stated, the atomistic condition reviewed the topic learning tasks in the first week, so a significant increase is expected in second week. Table 5 displays the average differences between these weeks for both conditions. Results shows both conditions significantly increase in knowledge. The results indicated no interaction effect of sequencing strategy on time ($F(4.469) = 1.685$, $p = .145$). Meaning, both strategies showed a similar increase in knowledge and do not differ during the course. Because the conditions do not statistically differ, there is no difference in in-depth knowledge between the conditions.

Table 5

Average difference in knowledge level on between the weeks

Component	Week		Atomistic			Holistic		
	From	To	*M*	*t(47)*	*p*	*M*	*t(47)*	*p*
Learning tasks	1	2	1.396	4.116	.003	1.479	4.426	.001
Supportive information	4	5	3.458	7.361	<.001	0.979	2.699	.202
Procedural information	5	6	3.750	6.949	<.001	0.604	1.522	1.000
Part task practice	6	7	0.667	2.498	.337	0.292	1.180	1.000

Note. The displayed mean score indicates the average increase between the two weeks.

Figure 3

Card Sorting Task Score Sequencing Conditions on Learning tasks Component

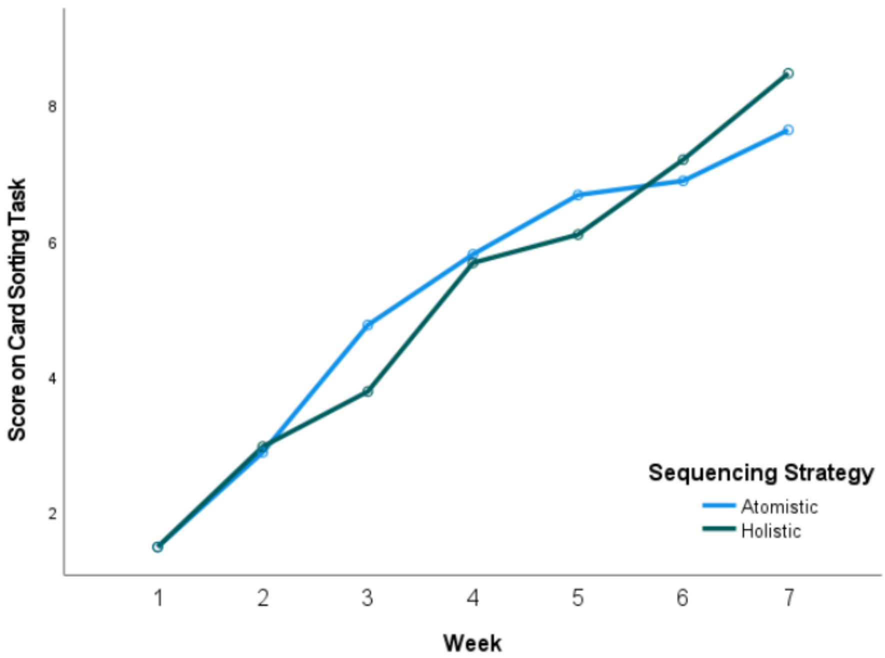


Figure 4 shows students' average score during the course on the component supportive information. The atomistic condition discussed this topic in the fourth week, so an increase on the card sorting task score is expected in week 5. The increase for the atomistic condition is significant. Whereas, unlike the hypothesis, the holistic condition did not increase (see Table

5). Furthermore, to analyse if one condition has more in-depth knowledge than the other, it was checked if the conditions statistically differed. A significant interaction effect with a medium effect size was found between sequencing condition and time ($F(5.089) = 10.109$, $p < .001$, $\eta^2 = .097$). Implying that the scores on supportive information differed for the sequencing conditions somewhere during the course. However, focused on the difference between the strategies in week 5, the analysis showed no statistical difference between the two conditions ($t(1) = 1.895$, $p = .061$). So, one condition did not have more in-depth knowledge than the other in week 5.

Figure 4

Card Sorting Task Score Sequencing Conditions on Supportive Information Component

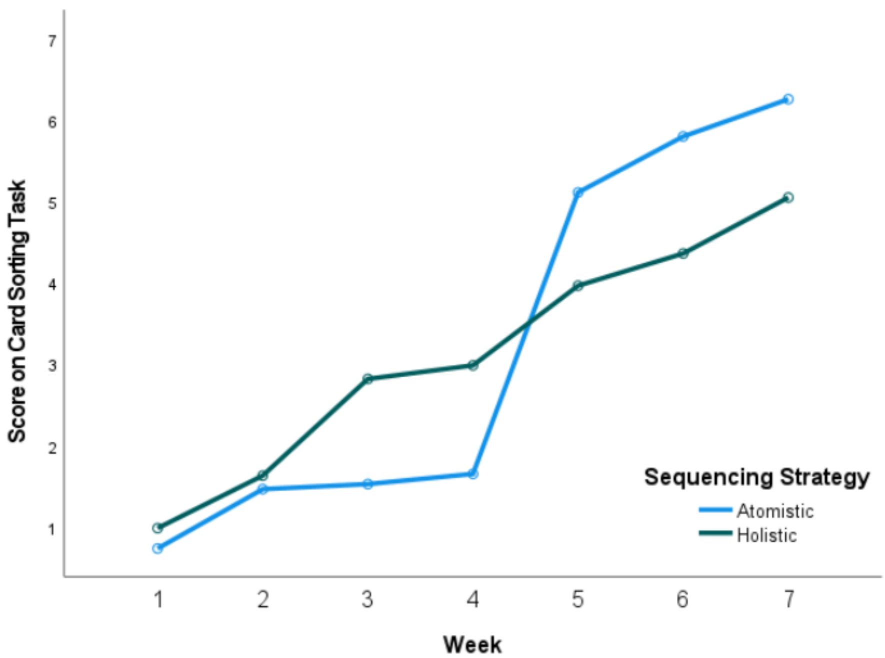
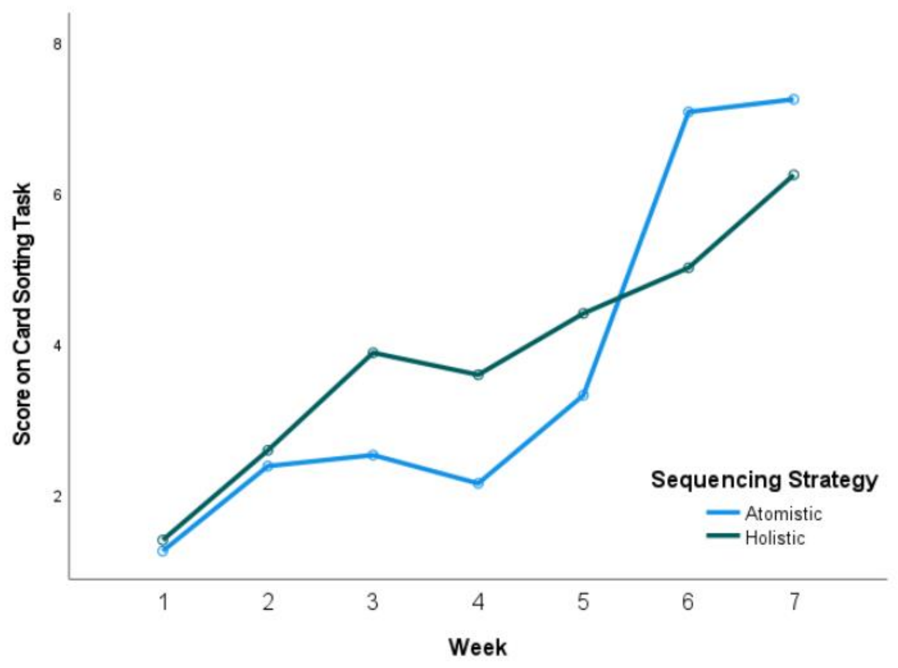


Figure 5 shows the trajectory of the procedural information component. Because the atomistic condition discussed the topic during week 5, a significant difference in score is expected in week 6. As presented in Table 5, the atomistic condition scored significantly higher in week 6 than week 5, whereas the holistic condition did not significantly increase. This is in contrast with the hypothesis. Furthermore, a significant interaction effect was found between sequencing condition and time ($F(3.741) = 10.597$, $p < .001$, $\eta^2 = .101$). The size effect can be considered medium. Meaning, the scores between the conditions differed significantly somewhere during the course. When comparing weeks 5 and week 6, the atomistic condition scored significantly higher with a medium effect size ($t(1) = 3.138$, $p = .002$, $\eta^2 = .095$). This indicates that students receiving atomistic serialized web lectures had more in-depth knowledge in week 6 than the holistic condition.

Figure 5

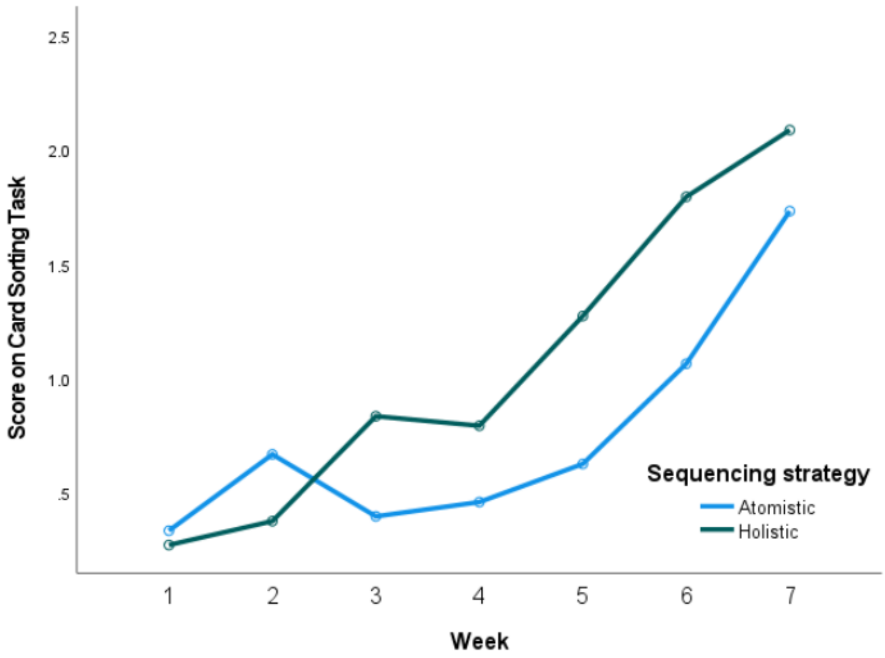
Card Sorting Task Score Sequencing Conditions on Procedural Information Component



Finally, Figure 6 displays the trajectory for the part task practice component over the course. The atomistic condition received information during the sixth week, thus the card sorting task score on the seventh week will be analysed to indicate if students gained knowledge on the topic part task practice. The scores of the atomistic and holistic conditions did not increase between the sixth and seventh week. The statistics are shown in Table 5. Further, the component showed an interaction effect between the sequencing strategy and time (F(3.811) = 2.709, p = .032, η^2 = .028). The effect size is small. The two conditions differ at least one moment during the course. But, the strategies did not differ significantly in week 7 (t(1) = -.911, p = .365). So, both strategies had the same level of in-depth knowledge.

Figure 6

Card Sorting Task Score Sequencing Conditions on Part Task Practice Component



Discussion

Teachers increasingly apply FCA, but struggle with the appropriate sequencing design. In contrast to other studies on instructional video clip sequencing, this study focused on macro level sequencing; the order between multiple videos in a course. Differential effects of two sequencing strategies were examined, providing insight into the most effective sequencing design of web lectures to facilitate knowledge acquisition. Participants received atomistic or holistic sequenced web lectures during a flipped course. They participated in a weekly online modified card sorting task to test their domain-specific knowledge acquisition. Comparing the two sequencing strategies let to the answer on the research question: *What are the differential effects of atomistic sequenced web lectures and holistic sequenced web lectures on the knowledge acquisition process in a flipped learning course?*

Focused on the core concept of the course, the results show that the atomistic and holistic condition do not differ in the knowledge acquisition process, with the exception for the fourth week. In that week the holistic condition scored higher, but that difference was small and recuperated in the next week. In all other weeks the strategies did not differ. The results provide little support for the first hypothesis that stated the two strategies differed during the course. One can conclude that students' knowledge acquisition of the core concept in a flipped course is not largely influenced by the sequencing strategy of their web lectures.

The second hypothesis focused on in-depth knowledge. It was presumed both strategies increased in in-depth knowledge on a topic and did not differ in in-depth knowledge after the atomistic condition discussed the topic in class. Results are mixed. The learning tasks topic was as hypothesised. The atomistic condition as well as the holistic condition increased in knowledge after the week the atomistic condition discussed the topic in class. Furthermore, the strategies did not differ in in-depth knowledge. The other three topics show one or two not hypothesised results. The holistic condition did not increase in knowledge in the week the atomistic condition reviewed the topic supportive information. However, the atomistic condition did increase and the conditions did not differ on in-depth knowledge. For the procedural information topic, again the atomistic condition increased in knowledge and the holistic condition did not. In addition, the sequencing strategies differed on in-depth knowledge, in favour of the atomistic condition. Lastly, not following the hypothesis, both conditions did not increase in knowledge on the part task practice topic. However, both strategies had to the same level of in-depth knowledge. Generally, the results show that atomistic sequencing led to a significant increase in in-depth knowledge after the topic is discussed. The holistic strategy is not that conclusive about the increase in in-depth knowledge. Furthermore, as expected, one condition does not lead to higher in-depth knowledge than the other after the atomistic condition discussed the topic in class.

To answer the research question, there are few differences in knowledge acquisition between atomistic and holistic sequenced web lectures in a flipped learning course. Both strategies have relatively the same trajectory and do not differ remarkably during the course. Continuing, knowledge acquisition in the atomistic strategy does increase after the topic is discussed, this does not lead to difference between condition in in-depth knowledge in those weeks.

The results of this current study seem to correspond with arguments in previous research, but are not completely in line. Previous research implied that the holistic sequencing strategy leads to better knowledge acquisition (Lim et al., 2008, van Merriënboer & Kirschner, 2018). Students learn the whole task and all topics would be reviewed and learned more constantly and easily (Reigeluth, 2007). Although, some literature backs atomistic sequencing to lead to better knowledge acquisition. Due to the focus on one specific topic, students would create more in-depth knowledge than in the holistic condition and therefore better acquired knowledge (Reigeluth, 2007). The small difference found in favour of the holistic condition can be explained by the argument in the holistic literature. But, the arguments in favour of the atomistic strategy can explain why it is only a small difference.

The difference between literature and results about in-depth knowledge can somewhat be explained by Reigeluth (2007). He describes that because topics are periodically reviewed in a holistic design, the topics might be learned more in-depth. But, he also states that by atomistic instruction students can concentrate on one topic without frequently skipping to new topics, which could lead to more in-depth knowledge. Both arguments describe how each sequencing strategy could lead to higher in-depth knowledge. Both arguments can be true and therefore, in the current study, the strategies have equal in-depth knowledge.

Disparity between the findings and previous research might have to do with the FCA. Previous research has not focused on the setting, but merely on video instructions. Other activities that students had in this study (e.g., attend tutorial meetings, do a group assignment, and an exam) could have had an impact on the knowledge acquisition process. Students in both conditions were engaged with the course content in multiple ways. Therefore, different sequencing strategies might have been a too little modification to have an impact because the other activities compensated possible variations in the knowledge level.

FCA might not be the only explanation for the differences between literature and the results of this study. Hence, three limitations to this research will be discussed. The first limitation is that in the card sorting task not all topics had the same number of answers. Therefore, it was impossible for, for example the part task practice component, to create significant differences between the conditions. This might have influenced the results. Statistical difference might not have been found due to number students possibly could get. When all components had the same number of terms, results including the components, could have a higher valid value.

The second limitation regards the sample size. The sample size consisted of 394 participants. Unfortunately, 75.63% missed (demographic) information or card sorting task results and were therefore excluded. This research only included the ones that provided all information. When more participants took part of this study, respondents fulfilled all measurements, or this study also included respondents that did not participated in all measurements, differences between sequencing strategy might have been significant. More respondent could increase the reliability of the results.

The final limitation, students were not obligated to watch the videos at a specific moment of day. Therefore, students could have watched videos later than when they should which could have influenced the test performance. Every week, students received a series of videos to watch, which was needed for active participation during the tutorial session. Students could have watched one video and see the others after doing the card sorting task. This possibility could have influenced the knowledge acquisition process and thus the card soring task performance. Provided information might not have been acquired evenly and possibly let a disparity in results. Information could be learned in later weeks, which could let to a lower knowledge acquisition in some weeks and higher acquisition in others.

Future research into the two sequencing strategies and the differential effects in a flipped learning course should include more participants in the study and even the answers of the in-depth topics. Also, future research should consider testing more sequencing strategies. This research focuses on atomistic and holistic research, but strategies as 'snowballing' were not investigated. Alternatives to the used strategies could provide a more complete view of sequencing strategies on knowledge acquisition. Finally, because this research focused on sequencing as part of flipped classroom design, other factors like presentation and method can affect knowledge acquisition in a flipped course. Those affects are also important to overcome the lack in design knowledge teachers have.

This research proved insight into two sequencing strategies for web lectures teachers can implement in their flipped classroom course. Results show that the strategy does not largely influence the knowledge acquisition process of the students. There might be a slight preference for holistically sequenced video instructions. But the results are not very decisive. When looking at in-depth knowledge of topics, there might be a small preference for the atomistic strategy. Again, the results are not very forceful. Students' knowledge level does not provide arguments deciding which strategy teachers should implement. Therefore, helping teachers decide with strategy they should implement, it is recommended to choose for the strategy that has a lower workload and efficient management of learning materials (Reigeluth, 2007; Wopereis et al., 2016). Thanks to this research, teachers have more insight into the macro level sequencing strategy of their video instructions and students' knowledge acquisition.

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Appendix A

Online Modified Card Sorting Task

	Ik weet het niet	Leertaken	Ondersteunend…	Procedurele inf…	Deeltaakoefeni…
Adaptive learni…	○	○	○	○	○
Backward chai…	○	○	○	○	○
Case study	○	○	○	○	○
Causal model	○	○	○	○	○
Cognitive feedb…	○	○	○	○	○
Cognitive rule	○	○	○	○	○
Cognitive strate…	○	○	○	○	○
Completion str…	○	○	○	○	○
Component flu…	○	○	○	○	○
Conceptual mo…	○	○	○	○	○
Contextual inte…	○	○	○	○	○
Corrective feed…	○	○	○	○	○
Demonstration	○	○	○	○	○
Domain model	○	○	○	○	○
Elaboration	○	○	○	○	○
Emphasis mani…	○	○	○	○	○
Fading	○	○	○	○	○
Fidelity	○	○	○	○	○
Fractionation	○	○	○	○	○
Guidance	○	○	○	○	○

IF-THEN rule	○	○	○	○	○
Inductive learni...	○	○	○	○	○
Instance	○	○	○	○	○
Just-in-time inf...	○	○	○	○	○
Knowledge pro...	○	○	○	○	○
Mental model	○	○	○	○	○
Overlearning	○	○	○	○	○
Performance c...	○	○	○	○	○
Plan	○	○	○	○	○
Prerequisite kn...	○	○	○	○	○
Principle	○	○	○	○	○
Procedure	○	○	○	○	○
Process works...	○	○	○	○	○
Rule formation	○	○	○	○	○
Scaffolding	○	○	○	○	○
Segmentation	○	○	○	○	○
Simplification	○	○	○	○	○
Simplifying con...	○	○	○	○	○
Strengthening	○	○	○	○	○
Support	○	○	○	○	○
Systematic App...	○	○	○	○	○
Task class	○	○	○	○	○
Variability of pr...	○	○	○	○	○
Whole-task seq...	○	○	○	○	○

Appendix B

Assumptions

Before conducting the mixed MANOVA and mixed ANOVAs, assumptions for normal distribution, outliers, homogeneity of variances, and sphericity were checked. Table B1 shows the statistics of the Shapiro-Wilk Test of Normality and Levine's Test for Homogeneity of Variances. Outliners were detected by examining boxplots. Sphericity was determined by Mauchly's Test of Sphericity.

Table B1 shows that not all weeks had a normal distribution. Even when there is a non-normal distribution, in some cases the MANOVA and ANOVAs can still be performed without an increased Type 1 error (Blanca et al., 2017). When analysing the histograms of the weeks in both conditions, these weeks seem quite normal distributed. Also, research indicate that if populations have the same distributional shape (Kirk, 2013) and sample sizes are large and equal (Winer et al., 1991), like in this study, ANOVA is robust. Therefore, the assumption of normal distribution for the total score is adopted. The test for homoscedasticity showed not all weeks had an equality across variances. Because ANOVA is not particular sensitive to violations when samples are moderate to large and equal in size, the assumption of homoscedasticity can be adopted. Outliers were detected and reviewed in the dataset. There is no valid argument to remove these participants from the data. For the mixed MANOVA, Mauchly's Test of Sphericity is significant for the main component score ($W(5) = 0.599$, $p < .001$, $\varepsilon = .779$). For the interaction between component and time, the specificity is significant as well ($W(170) = 0.09$, $p < .001$, $\varepsilon = .658$). Mauchly's test for the mixed ANONVAs also showed a significant results for the total score ($W(20) = 0.190$, $p < .001$, $\varepsilon = .583$), learning tasks score ($W (20) = 0.407$, $p < .001$, $\varepsilon = .745$), supportive information score ($W(20) = 0.455$, $p < .001$, $\varepsilon = .848$), procedural information score ($W(20) = 0.237$, $p < .001$, $\varepsilon = .623$), and part task practice score ($W(20) = 0.184$, $p < .001$, $\varepsilon = .635$). In conclusion, some assumptions for the MANOVA and ANOVA have been violated, but based on research and use of corrections, the analyses could have been performed.

Table B1

Results Test of Normality and Homoscedasticity Mixed MANOVA and Mixed ANOVA

Course week	Component	Shapiro-Wilk				Levine's test	
		Atomistic		Holistic			
		W(48)	*p*	*W*(48)	*p*	*F*(1, 94)	*p*
Week 1	Learning tasks	.803	<.001	.841	<.001	.348	.557
	Supportive information	.652	<.001	.739	<.001	.733	.394
	Procedural information	.797	<.001	.849	<.001	.445	.506
	Part task practice	.575	<.001	.463	<.001	.143	.706
	4C/ID	.866	<.001	.891	<.001	.067	.797
Week 2	Learning tasks	.920	.003	.910	.001	.105	.747
	Supportive information	.793	<.001	.805	<.001	.234	.630
	Procedural information	.886	<.001	.877	<.001	1.899	.171
	Part task practice	.575	<.001	.517	<.001	3.566	.062
	4C/ID	.893	<.001	.921	.003	.118	.179
Week 3	Learning tasks	.962	.126	.917	.002	.698	.406
	Supportive information	.761	<.001	.893	<.001	4.677	.033
	Procedural information	.917	.002	.922	.004	8.607	.004
	Part task practice	.615	<.001	.732	<.001	13.797	<.001
	4C/ID	.956	.069	.947	.030	7.280	.008
Week 4	Learning tasks	.963	.139	.953	.051	1.754	.189
	Supportive information	.729	<.001	.886	<.001	4.579	.035
	Procedural information	.889	<.001	.941	.017	7.666	.007
	Part task practice	.643	<.001	.705	<.001	7.317	.008
	4C/ID	.934	.009	.964	.140	9.571	.003
Week 5	Learning tasks	.948	.032	.940	.016	4.294	.041
	Supportive information	.915	.002	.925	.004	.156	.694
	Procedural information	.889	<.001	.928	.006	3.761	.055
	Part task practice	.639	<.001	.770	<.001	9.127	.003
	4C/ID	.990	.954	.969	.225	9.125	.003
Week 6	Learning tasks	.979	.519	.947	.030	7.184	.009
	Supportive information	.917	.002	.934	.009	.003	.958
	Procedural information	.951	.044	.950	.041	.635	.428
	Part task practice	.679	<.001	.845	<.001	1.070	.303
	4C/ID	.965	.162	.985	.786	2.049	.156
Week 7	Learning tasks	.944	.023	.943	.021	7.696	.007
	Supportive information	.931	.008	.911	.001	3.487	.065
	Procedural information	.968	.215	.961	.111	3.689	.058
	Part task practice	.871	<.001	.831	<.001	1.198	.276
	4C/ID	.961	.111	.969	.231	7.771	.006

Appendix C

Exploratory Research: Learning Outcomes

Lim et al. (2008) investigated the learning outcome of atomistic and holistic sequencing instructional video instructions. They concluded that the holistic instruction group, got higher grades. Therefore, and based on the theoretical assumptions underlying Van Merriënboer and Kirschner's (2018) research and the findings of Lim et al. (2008), it was expected that holistic sequenced web lectures led to higher learning outcomes compared to atomistic sequenced videos.

To determine an effect of the conditions on the learning outcome, a one-way ANOVA was run with the atomistic and holistic condition as independent variable and course grade as dependent variable. The course grade is the average grade one got on an exam and group assignment. The exam consisted of 40% of the total grade, the group assignment 60%. These tests appealed to the theoretical and practical knowledge of the student and were granted at the end of the course.

The group assignment was a design assignment in which the students designed learning material for an instruction problem of an organization. Students worked together in groups of four, formed by the teacher. The groups wrote a legitimation report in which analyses and educational choices were validated and the implementation and evaluation were described. The exam was a closed book exam, consisting of multiple-choice questions and open questions. The exam tested the students' knowledge of current theories and methods for designing education session and knowledge into the phases of educational design processes. Also, students were needed to show their critically reflection on the educational design literature.

The groups for the group assignment were self-manageable. The groups were free to decide how they would handle the assignment. If necessary, the groups could get consultation from the teacher at the end of the tutorial meeting. In the final week of the course, the group needed to handle in their reports. In the same week, the exam was conducted. The tutorial teachers graded the assignment and exam based on a rubric.

The Shapiro-Wilk test of normality showed no significance result for the atomistic condition ($W(48) = .967$, $p = .186$) or the holistic condition ($W(48) = .966$, $p = .181$). Two outliers in the holistic condition were detected, but there is no indication for exclusion. Levene's test showed no significant result ($F(1, 94) = .845$, $p = .360$). Therefore, the assumptions to run a one-way ANOVA have not been violated.

The descriptive statistics shown in Table C1 indicate that the students in the atomistic condition had a slightly higher final grade than the students in the holistic condition. However, the one-way ANOVA showed no significant difference between the two conditions on the learning outcome ($F(1) = 2.499$, $p = 0.117$). The test scores of the atomistic condition did not differ significantly from the holistic condition. The sequencing condition had no effect on the students' learning outcome.

Table C1

Descriptive Statistics Exam, Group assignment, and Final Grade for the Two Conditions

Condition	Exam grade		Group assignment grade		Final grade	
	M	*SD*	*M*	*SD*	*M*	*SD*
Atomistic	6.726	0.991	7.415	0.959	7.139	0.786
Holistic	6.365	1.098	7.242	0.938	6.891	0.754
Total	6.546	1.056	7.323	0.947	7.015	0.776

Appendix D

Exploratory Research: Knowledge Trajectory

The present study has looked at the in-depth knowledge gain at a specific moment during the course. Namely, after the atomistic condition received the information. Therefore, knowledge was expected to increase after that week. Unfortunately, the research did not look at the knowledge gain of the specific topics over the whole course. One could question the difference in in-depth knowledge of the separate components between each sequencing strategy seen over the whole course. Furthermore, it could be questioned how steep the knowledge gain proceeds during the course.

As described in the research, knowledge about the component learning tasks did not differ between the two strategies during the course ($F(4.469) = 1.685$, $p = .145$). In all weeks, the two conditions had relatively the same score on the learning tasks topic. The sequencing strategy had no effect on how good the students sorted the terms to the component learning tasks.

For the component supportive information, as described, was a medium significant interaction effect found between sequencing condition and time ($F(5.089) = 10.109$, $p < .001$, $\eta^2 = .097$). Students in the holistic condition scored significantly higher in week 3 ($t(1) = -2.746$, $p = .007$, $\eta^2 = .074$) and week 4 ($t(1) = -2.832$, $p = .006$, $\eta^2 = .079$). The atomistic sequencing condition scored significantly higher in week 6 ($t(1) = 2.561$, $p = .012$, $\eta^2 = .065$) and week 7 ($t(1) = 2.250$, $p = .027$, $\eta^2 = .051$). In week 3 the differences was 1.29 terms, in week 4 1.33 terms, in week 6 1.44 terms, and in week 7 1.21 terms.

A medium significant interaction effect found between sequencing strategy and time for the component procedural information ($F(3.741) = 10.597$, $p < .001$, $\eta^2 = .101$). The domain-specific knowledge in week 3 ($t(1) = -2.610$, $p = .011$, $\eta^2 = .068$) and week 4 ($t(1) = -$

3.111, p = .002, η^2 = .093) were significantly higher for students in the holistic condition. The difference was respectively 1.36 points and 1.43 points. In week 6, the students in the atomistic condition scored 2.06 points higher, which was significant (t(1) = 3.138, p = .002, η^2 = .095).

Finally, the component part task practice showed a small interaction effect between condition and time (F(3.811) = 2.709, p = .032, η^2 = .028). In week 3 (t(1) = -2.213, p = .029, η^2 = .050), week 5 (t(1) = -2.245, p = .027, η^2 = .051), and week 6 (t(1) = -2.052, p = .043, η^2 = .043) the students in the holistic condition sorted significantly more term correctly. In week 3 the difference was 0.43, in week 4 0.64, and in week 6 0.73 terms. The students in the atomistic condition never scored significantly higher.

Table 4 show the average scores the participants had on the learning tasks, supportive information, procedural information, and part task practice topic during the course. Table D1 show the average differences between the weeks focused on the learning tasks component. Focussing on the atomistic strategy, there are six comparisons that show no difference in score on the component learning tasks. Around week 4, the students do not seem to gain knowledge on learning tasks. The holistic condition did not differ on the score on learning tasks between weeks in four comparisons. Like the students in the atomistic condition, the students in the holistic condition does not seem to gain much knowledge on the concept of learning tasks from week 4.

Table D1

Average Difference in Knowledge Level on Learning tasks Component Between the Weeks

Week		Atomistic		Holistic	
From	To	*M*	*p*	*M*	*p*
1	2	-1.396	.003	1.479	.001
1	3	3.271	<.001	2.292	<.001
1	4	4.312	<.001	4.187	<.001
1	5	5.187	<.001	4.604	<.001
1	6	5.396	<.001	5.708	<.001
1	7	6.146	<.001	6.979	<.001
2	3	1.875	<.001	0.812	.910
2	4	2.917	<.001	2.708	<.001
2	5	3.792	<.001	3.125	<.001
2	6	4.000	<.001	4.229	<.001
2	7	4.750	<.001	5.500	<.001
3	4	1.042	.198	1.896	.007
3	5	1.917	<.001	2.312	<.001
3	6	2.125	<.001	3.417	<.001
3	7	2.875	<.001	4.687	<.001
4	5	0.875	.566	0.417	1.000
4	6	1.083	.386	1.521	.074
4	7	1.833	.001	2.792	<.001
5	6	0.208	1.000	1.104	.524
5	7	0.958	.450	2.375	.001
6	7	0.750	.410	1.271	.030

Note. The displayed mean score indicates the average increase between the two weeks.

As seen in Table D2, for the component supportive information, the total scores did not statistically differ between week 2 and week 3, week 3 and week 4, week 5 and week 6, and week 6 and week 7. The atomistic strategy showed no significant increase during the first four weeks and no significant increase during the last three. The holistic condition seems to slowly increase in knowledge and stops from week 5. The knowledge gain is only significant after multiple weeks.

Table D2

Average Difference in Knowledge Level on Supportive Information Component Between the Weeks

Week		Atomistic		Holistic	
From	To	*M*	*p*	*M*	*p*
1	2	0.729	.070	0.646	.396
1	3	0.792	.031	1.833	<.001
1	4	0.917	.060	2.000	<.001
1	5	4.375	<.001	2.979	<.001
1	6	5.062	<.001	3.375	<.001
1	7	5.521	<.001	4.062	<.001
2	3	0.062	1.000	1.187	.044
2	4	0.187	1.000	1.354	.004
2	5	3.646	<.001	2.333	<.001
2	6	4.333	<.001	2.729	<.001
2	7	4.792	<.001	3.417	<.001
3	4	0.125	1.000	0.167	1.000
3	5	3.583	<.001	1.146	.045
3	6	4.271	<.001	1.542	.007
3	7	4.729	<.001	2.229	<.001
4	5	3.458	<.001	0.979	.202
4	6	4.146	<.001	1.375	.013
4	7	4.604	<.001	2.062	<.001
5	6	0.687	1.000	0.396	1.000
5	7	1.146	.452	1.083	.223
6	7	0.458	1.000	0.687	.818

Note. The displayed mean score indicates the average increase between the two weeks.

Table D3 shows the average scores on procedural information for the two sequencing strategies as well as for the total participating group. All three group increases, but in the descriptive statistics one could detect a decay in week 4. Beware, that decay is not significant. Focused on the atomistic strategy group, week 4 is lower in score than the second and third week, but again, that difference is non-significant. Like by the topic of supportive information, the second till fifth week the students gain little to no knowledge, then increase significantly and end the course with a stagnation. Furthermore, focussing on the holistic condition, seven comparisons show no increase. Indicating that the knowledge slowly increases, which can only be seen over multiple weeks.

Table D3

Average Difference in Knowledge Level on Procedural Information Component Between the Weeks

Week		Atomistic		Holistic	
From	To	*M*	*p*	*M*	*p*
1	2	1.125	.008	1.187	.001
1	3	1.271	.002	2.479	<.001
1	4	0.896	.015	2.187	<.001
1	5	2.062	<.001	3.000	<.001
1	6	5.812	<.001	3.604	<.001
1	7	5.979	<.001	4.833	<.001
2	3	0.146	1.000	1.292	.002
2	4	-0.229	1.000	1.000	.063
2	5	0.937	.568	1.812	.001
2	6	4.687	<.001	2.417	<.001
2	7	4.854	<.001	3.646	<.001
3	4	-0.375	1.000	-0.292	1.000
3	5	0.792	1.000	0.521	1.000
3	6	4.542	<.001	1.125	.605
3	7	4.708	<.001	2.354	<.001
4	5	1.167	.064	0.812	1.000
4	6	4.917	<.001	1.417	.073
4	7	5.083	<.001	2.646	<.001
5	6	3.750	<.001	0.604	1.000
5	7	3.917	<.001	1.833	.002
6	7	0.167	1.000	1.229	.006

Note. The displayed mean score indicates the average increase between the two weeks.

Finally, Table D4 shows the comparisons between the mean scores for the component part task practice. Quite a lot of contrasts show no increase in knowledge. During the first three weeks, all groups show no gain in knowledge. More striking, the atomistic condition did not show development during the first five weeks. The descriptive statistics indicate a decay in knowledge from week 2 to week 3 for the atomistic condition, but as that difference not significant. Also, the descriptive statistics show a lower score in week 4 than in week 3 in the holistic condition, which could indicate a decay, but again this difference is not significant. The holistic condition does show growth in week 5 compared to the first and second week, but not gains that much afterwards.

Table D4

Average Difference in Knowledge Level on Part Task Practice Component Between the Weeks

Week		Atomistic		Holistic	
From	To	*M*	*p*	*M*	*p*
1	2	0.333	.929	0.104	1.000
1	3	0.062	1.000	0.562	.046
1	4	0.125	1.000	0.521	.202
1	5	0.292	1.000	1.000	.009
1	6	0.729	.045	1.521	<.001
1	7	1.396	<.001	1.812	<.001
2	3	-0.271	1.000	0.458	.337
2	4	-0.208	1.000	0.417	.837
2	5	-0.042	1.000	0.896	.025
2	6	0.396	1.000	1.417	<.001
2	7	1.062	.002	1.708	<.001
3	4	0.062	1.000	-0.042	1.000
3	5	0.229	1.000	0.437	1.000
3	6	0.667	.059	0.958	.005
3	7	1.333	<.001	1.250	.005
4	5	0.167	1.000	0.479	.276
4	6	0.604	.273	1.000	.004
4	7	1.271	<.001	1.292	.002
5	6	0.437	1.000	0.521	1.000
5	7	1.104	<.001	0.812	.062
6	7	0.667	.337	0.292	1.000

Note. The displayed mean score indicates the average increase between the two weeks.

The trajectory of the knowledge gain of the core-concept (4C/ID) of the course can also be described. Identifying the steepness of the knowledge increase on 4C/ID of two strategies can provide insight into how much new knowledge participants gain every week during the course. On average students got on average 18.365 more terms correctly sorted between week 1 and week 7. As described in this research, results show that every week the participants scored a significant higher score on the test than the week before, except between week 3 and week 4. This stabilisation applies for the average score regardless the sequencing strategy, as well for the atomistic and holistic strategy independently. The mean differences with significance level are shown in Table D5. When focused on the separate strategies, the results show that the average holistic condition scores in week 4 do not statistically differ from week 5. Furthermore, week 5 does not statistically differ from week 6. So, the increase for the holistic condition seems to slow down from around week 4.

Table D5

Average Difference in Knowledge Level on 4C/ID Between the Weeks

Week		Atomistic		Holistic	
From	To	*M*	*p*	*M*	*p*
1	2	3.583	<.001	3.417	<.001
1	3	5.396	<.001	7.167	<.001
1	4	6.250	<.001	8.896	<.001
1	5	11.917	<.001	11.583	<.001
1	6	17.000	<.001	14.208	<.001
1	7	19.042	<.001	17.687	<.001
2	3	1.812	.048	3.750	<.001
2	4	2.667	<.001	5.479	<.001
2	5	8.333	<.001	8.167	<.001
2	6	13.417	<.001	10.792	<.001
2	7	15.458	<.001	14.271	<.001
3	4	0.854	1.000	1.729	1.000
3	5	6.521	<.001	4.417	.002
3	6	11.604	<.001	7.042	<.001
3	7	13.646	<.001	10.521	<.001
4	5	5.667	<.001	2.687	.135
4	6	10.750	<.001	5.312	<.001
4	7	12.792	<.001	8.792	<.001
5	6	5.083	<.001	2.625	.558
5	7	7.125	<.001	6.104	<.001
6	7	2.042	.016	3.479	.001

Note. The displayed mean score indicates the average increase between the two weeks.

During the course thee of the four in-depth topics differed significantly between the strategies at some moments during the course. Meaning, that one strategy let to more in-depth knowledge than the other strategy. For three of the four topics, the holistic strategy let to more in-depth knowledge in the middle of the course. But, when the atomistic condition covered all topics (near the end of the course), for two of these three topics, the atomistic condition let to higher in-depth knowledge. In the span of two weeks, the students in the atomistic condition have coughed up and somewhat enlarged their in-depth knowledge level compared to the holistic condition. In sum, the atomistic strategy let to higher in-depth knowledge than the holistic condition, but that only is when the subject is discussed in the classroom, until that time, the holistic condition leads to a higher in-depth knowledge.

Analysing the progression of knowledge from week to week, the knowledge on the core concept the holistic condition slows down from week 4. But as described in this study, the differences between the two strategies in the end are not significant. So, the delay in knowledge acquisition seems not problematic. Knowledge acquisition for the separate components in the atomistic condition show that the topics are only learned when they are specifically presented. Therefore, increases in knowledge are sporadic and students do not gain much knowledge afterward. The holistic condition on the other hand, show a more constant, but slow increase. It seems that the holistic condition shows a more stable, slow increase, compared to the more stepwise increase by the atomistic sequencing strategy.