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Does in-class modality affect flipped learning? Designing a higher education flipped classroom using the 5E instructional model

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Abstract

Flipped classrooms can support active learning in higher education. However, evidence is less clear about how in-class modality, performance, and affective processes interact, and educators may struggle with designing theory-informed flipped classrooms. This study addresses these issues by implementing the 5E instructional model in two otherwise analogous flipped classroom conditions with fully online or face-to-face in-class lessons. In a longitudinal quasi-experimental design, *N* = 113 students in a German social science research methods course completed five lessons. Overall outcomes were broadly similar across modalities. The face-to-face condition only showed a small-to-moderate statistical advantage in declarative knowledge. Longitudinal analyses indicated a significant interaction between time and modality for application-oriented knowledge acquisition. A path model further showed that declarative knowledge predicted application-oriented knowledge, while academic self-efficacy predicted social relatedness and learning satisfaction, which social relatedness also predicted. Therefore, performance and affect were not significantly associated. The findings illustrate how the 5E model can translate constructivist principles into concrete flipped-classroom activities and suggest that instructional design and modality-tailored scaffolding warrant attention for effective flipped classrooms.

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Practitioner Notes

1. Use a theory-informed framework such as the 5E model to guide decisions of instructional design.
2. Consider modality decisions for flipped classrooms alongside instructional goals and context, given broadly similar results in this study. Offer students a choice, if possible.
3. Support students through scaffolding, deliberate design choices for tasks, and assessment to foster broadly equivalent performance between modalities.
4. Do not use learning satisfaction as a proxy for learning. In this study, satisfaction was associated with self-efficacy and social relatedness, but not with the knowledge measures.
5. Capture preparation behaviour for future implementations so that differences in how students engage with pre-class materials can be examined directly.

Keywords

Flipped classroom, Higher education, Knowledge acquisition, 5E instructional model, In-class modality

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Introduction

Flipped classrooms move initial exposure to course content before class. As a result, scheduled in-class time can be used for guided application, discussion, feedback, and other active learning activities (Strelan et al., 2020). In higher education, meta-analytic evidence indicates that flipped learning can produce small to moderate improvements for academic outcomes for students when compared with more conventional instruction (Bredow et al., 2021; Strelan et al., 2020). However, evidence of an overall benefit does not tell educators how to design a flipped lesson (Schallert et al., 2020), or whether a particular delivery modality is necessary for those benefits. Frameworks for designing flipped classroom instruction can provide guidance. They are important because flipped classrooms can vary widely in their learning activities, technologies, sequencing, and instructor involvement (Bredow et al., 2021). Systematic reviews have identified the diversity of designs as a continuing challenge and have noted a need for stronger theoretical grounding of flipped-classroom research (Baig & Yadegaridehkordi, 2023; Schmid et al., 2023). Utilising an existing, theory-driven framework can therefore serve two purposes: it can make instructional decisions more explicit, and it can provide a common structure to compare different delivery modalities within.

The present study uses the 5E instructional model as that common structure. The model organises learning into Engage, Explore, Explain, Elaborate, and Evaluate phases and is grounded in constructivist accounts of learning (Ruiz-Martín & Bybee, 2022). Although the model has been used extensively in schools, evidence indicates that it can be adapted beyond science education at this level (Joswick & Hulings, 2024; Mukagihana et al., 2022). Its value for flipped learning in higher education lies in linking the pre-class and in-class portions of a course to a sequence of cognitive and social learning functions: activating prior knowledge, making current understanding visible, providing feedback, extending knowledge through application, and evaluating learning.

Fully online and face-to-face flipped classrooms can implement the same active learning principles, but modality may shape students' experiences, including interaction and participation. Existing findings are mixed: some studies report advantages for face-to-face learning in social or motivational outcomes, whereas other evidence finds comparable or better performance online (Schmid et al., 2023). Direct comparisons are also difficult when instructional designs differ across modalities. The present study addresses this problem by using the same 5E-informed lesson structure, learning materials, assessments, and instructor in both conditions. Another question concerns the relationship between achievement and affect. Flipped learning research commonly reports performance and student perceptions separately, leaving uncertainty about how these outcomes are connected within a single instructional design. By examining self-efficacy alongside knowledge acquisition, social relatedness, and learning satisfaction, the study therefore seeks to provide insight into these relationships.

Additionally, the study gathers longitudinal evidence, which both researchers and practitioners have called for in flipped classroom research (Baig & Yadegaridehkordi, 2023; ElGamal, 2025). Such evidence is needed because flipped learning is not a single exposure: students repeatedly prepare, participate, receive feedback, and apply knowledge across lessons. The present study therefore examines five consecutive lessons in a social science research methods course. In summary, the study makes three linked contributions. First, it provides a concrete account of how

the 5E model can be translated into a higher education flipped-classroom sequence. Second, it compares fully online and face-to-face in-class delivery within a common instructional framework. Third, it examines relationships among knowledge, self-efficacy, social relatedness, and satisfaction.

Literature

The 5E instructional model: from a social constructivist foundation to an actionable teaching framework

The 5E model of instruction (Bybee et al., 2006) is an instructional framework. It is built from a constructivist view of learning (Ruiz-Martín & Bybee, 2022) and provides a five-step sequence in which learners engage with a topic, explore ideas and prior conceptions, explain their understanding, elaborate it through new applications, and evaluate learning. Table 1 shows the goals and approaches of each phase according to Bybee (2014).

Systematic evidence indicates that the 5E model is effective in K–20 science education (Joswick & Hulings, 2024) and is among the most effective of twenty instructional methods used in pre-service teacher education (Mukagihana et al., 2022). Increasing adaptations in higher education (e.g., Bai et al., 2024; da Silva & de Vasconcelos, 2026) show the model's broader applicability. However, systematic reviews also report substantial heterogeneity, suggesting that improved science outcomes depend notably on how the phases are operationalised (Joswick & Hulings, 2024; Polanin et al., 2024). This is precisely where design choices become important. The model's theoretical relevance to flipped classrooms therefore lies in offering a principled way to distribute learning activities across pre-class and in-class activities.

Table 2 shows the chosen implementation for the present study. Engage and Explore were supported primarily through guided pre-class reading and questions that activated prior knowledge. Explain was employed through formative assessment and elaborated feedback. Elaborate was represented by cooperative, problem-based group tasks requiring application. Evaluate consisted of individual assessment of application-oriented knowledge. This mapping makes the theoretical contribution more specific: the study demonstrates a traceable connection between constructivist learning principles and the sequence of activities used in a higher education flipped classroom. This section explains each phase of the model and shows how it informed the instructional design used in this study.

Table 1

Five phases of the 5E model of instruction according to Bybee (2014)

Phase	Description
Engage	- Student engagement in a new concept through short activities promoting curiosity; elicitation of prior knowledge - Connection between past and present learning experiences, exposure of prior conceptions, organization of students' thinking toward the learning outcomes of current activities

Explore	- Common base of activities for identification of current concepts (i.e., misconceptions), processes, and skills; facilitation of conceptual change - Lab activities that help use prior knowledge for generation of new ideas, exploration of questions, and design and conduct of an investigation
Explain	- Focus of students' attention on a particular aspect of their engagement and exploration experiences - Opportunities for demonstration of conceptual understanding, processing of skills, or behaviours. - Introduction of a concept, process, or skill. Explanation from the teacher or other resources may critically guide learners toward a deeper understanding
Elaborate	- Challenge and extension of students' conceptual understanding and skills. - Development of deeper and broader understanding, more information, and adequate skills, through new experiences - Application of understanding of the concept and abilities by conducting additional activities
Evaluate	- Encouragement for students' assessment of their understanding and abilities - Teacher evaluation of student progress toward achieving the learning outcomes

Engage + Explore

For both the Engage and Explore phases, teachers are expected to help students connect past and present learning experiences. The pre-class component was designed to generate interest and activate prior knowledge rather than simply transmit information. To this end, guiding questions can support students' integrative knowledge building and structuring across domains (Lehmann, 2024). They may provide cognitive support for organising and elaborating knowledge structures (Thai et al., 2020) and encourage students to consider and apply domain-specific prior knowledge and skills during self-study (Moallem & Igoe, 2020). This approach reflects the 5E model's emphasis on learners' existing conceptions and provides a cognitive foundation for subsequent classroom work. After fostering students' self-guided learning in this manner, students are then encouraged to record and test their current ideas and understanding in the Explanation phase.

Explain

During this study, students made their current understanding visible through low-stakes, gamified formative assessment (Morris et al., 2021). Immediate automated feedback was supplemented by teacher explanation, allowing misconceptions to be addressed while the content was still active in working memory. This is consistent with the role of feedback as cognitive scaffolding, while leveraging that elaborated feedback in this manner can counteract possible negative effects from corrective feedback (Wagner et al., 2024). Gamified quizzes were chosen as they can serve as a vehicle for feedback and assessment (Morris et al., 2021). They may also enhance student performance (Sanchez et al., 2020), social relatedness (Zainuddin, 2020), and enthusiasm for learning (Bai et al., 2020). This makes them suitable for in-class segments of flipped classrooms

(Sailer & Sailer, 2021). In the next phase, Elaboration, students challenge, extend, deepen, and apply their knowledge.

Elaborate

To target higher-order learning, students completed a group task that required them to use their previously acquired knowledge in a new scenario. By engaging with the learning materials and with each other, students took part in cooperative tasks that operationalised the social-constructivist premise of interaction. Through cooperative learning, students' feelings of relatedness may be enriched (Fernandez-Rio et al., 2017; Van Ryzin & Roseth, 2018). In turn, enhanced social relatedness may improve students' sense of belonging in higher education (Allen et al., 2024). This may be especially important when some classes are held fully online rather than in the classroom. Lastly, the Evaluation phase deals with assessment of learning performance.

Evaluate

For this study, Evaluation was treated as both assessment and information for subsequent learning. Individual, application-oriented quizzes provided a learning activity by itself (Iwamoto et al., 2017), and a common measure of whether students could employ knowledge in domain-specific scenarios. This distinction between declarative and application-oriented knowledge is important because successful recall does not necessarily demonstrate transfer to a new situation. Furthermore, formative assessment during lessons may inform adjustments in scaffolding as well as future instructional design decisions in higher education flipped classrooms.

Affective variables: Academic self-efficacy, social relatedness, learning satisfaction

To investigate relationships between performance and affect, we draw on academic self-efficacy and social relatedness as variables. Academic self-efficacy (ASE) refers to students' beliefs about their capability to learn effectively and attain course goals (Bandura, 1977). It may be especially relevant in flipped settings because part of the learning process occurs without the immediate presence of the instructor. Evidence from online learning links ASE with student engagement (Wang et al., 2022). It may also influence student performance (Meng & Zhang, 2023). In this study, ASE is therefore treated as a potentially important individual difference that may influence student learning, not an outcome to be changed by course modality. Social relatedness (SR) is also relevant to flipped learning because collaborative activity can create opportunities for students to feel connected and valued. However, online and face-to-face settings may differ in how students experience such interaction. Meanwhile, learning satisfaction (LS) captures students' overall evaluation of the lesson. Critically, satisfaction should not be assumed to directly signify learning. Evidence on student evaluations suggests that favourable perceptions and cognitive learning outcomes can be only weakly related (Uttl et al., 2017). The present study consequently examines LS and student performance separately.

Performance variables: Declarative and application-oriented knowledge

In science education, the 5E model is often leveraged to foster declarative knowledge (Ünlü & Dökme, 2022). As a result, higher orders of learning, such as application, analysis and synthesis, may not be achieved (Ünlü & Dökme, 2022) and perhaps not even pursued. To test whether this

5E implementation fostered simple recall as well as transfer of knowledge in new, domain-specific scenarios, we measured the acquisition of declarative and application-oriented knowledge separately. This distinction also follows from the phase structure of the instructional model as implemented.

In-class course modality

Flipped classrooms can be implemented fully online or with face-to-face in-class lessons. Both approaches can foster constructivist learning (Fructuoso et al., 2022), and research has not determined a simple modality effect. Some studies report stronger relatedness or student perception of effectiveness in offline settings (Filak & Nicolini, 2018; Qin, 2025), while other studies find comparable or better learning outcomes online (Schmid et al., 2023). Such mixed findings may partly reflect differences in instructional design, course context, and student characteristics. Online flipped classrooms may face additional problems such as poor student participation and lack of tangible hands-on practice (Lo, 2023). A comparison in which the instructional sequence is deliberately held constant may therefore provide more interpretable evidence about the role of modality within a particular flipped design.

Research questions

Against this background, the following research questions were developed and investigated:

RQ1: Are there overall differences between students in the online or face-to-face in-class conditions when it comes to performance variables (acquisition of declarative and application-oriented knowledge) and affective variables (academic self-efficacy, social relatedness, and learning satisfaction)?

RQ2: To what extent do the development of declarative knowledge acquisition, application-oriented knowledge acquisition, and social relatedness differ across longitudinal measurements depending on course modality, while controlling for academic self-efficacy?

RQ3: What are the direct, predictive relationships between performance variables (acquisition of declarative and application-oriented knowledge) and affective variables (academic self-efficacy, social relatedness, and learning satisfaction) within our data?

Method

Research design and participants

The study used a longitudinal quasi-experimental design in an authentic university course. Participants selected either a fully online in-class condition or a face-to-face in-class condition; random assignment was therefore not used. Both conditions followed the same five-lesson, 5E-informed instructional design with matching learning materials, assessments, and instructor. The online condition used Zoom, with which students were already familiar.

The sample comprised 113 students (15 male, 98 female) enrolled in a required social science research methods course at a German university. Students were in semesters two to five of their programme. Before the first lesson, prior knowledge and epistemological beliefs were assessed; the groups did not differ significantly on these measures. Students with more than two missing measurement values were excluded from the relevant analyses of the anonymous questionnaires.

Because the study was conducted in a mandatory course, assessments were integrated into instruction where possible. Participation was based on informed consent. Data were anonymised using randomly generated identifiers and handled in accordance with GDPR requirements.

Measures

Social relatedness (SR)

SR was measured after each lesson using a three-item subscale adapted from Sailer (2016), with responses on a five-point agreement scale. Reliability across the five measurement occasions ranged from α = .781 to .911; overall reliability was α = .882. An example item is “During today’s lesson, I felt like I was part of a team.”

Academic self-efficacy (ASE)

ASE was measured with a translated seven-item, four-point scale adapted from Greene et al. (2004). It was administered in lessons 1, 3, and 5. Reliability was α = .855, .925, and .931, respectively. Because scores did not vary meaningfully across occasions, as expected, the aggregated ASE score was used as a covariate in the longitudinal analysis. An example item is “Compared to others in this class, I think I am good at learning the material of this course.”

Learning satisfaction (LS)

At the end of each lesson, students rated the lesson from 1 (worst possible rating) to 10 (best possible rating). Lesson ratings were aggregated for the overall modality comparison.

Declarative knowledge acquisition (DKA)

DKA was assessed in each lesson with a ten-item single-choice *Kahoot!* quiz administered after preparation and the instructional video. Gamification features were not included in the score; the proportion of correct responses was used.

A translated sample question is “What can lead to the formation of response patterns among survey participants? A) Monotony in long surveys (correct) B) Controversial questions at the start of surveys C) Transitions between thematic segments of the survey D) Omission of the icebreaker question in a survey.”

Application-oriented knowledge acquisition (AOKA)

AOKA was assessed with a ten-item, non-gamified *SoSciSurvey* quiz at the end of each lesson. Items presented domain-specific scenarios requiring students to apply previously learned concepts.

A translated sample question is “In this lesson, you have learnt about conducting content analyses for German texts. Now imagine you want to compare and contrast the lexical variety of an English text and a German text. What do you have to look out for? A) The language of the texts is irrelevant for the type-token ratio B) Texts in different languages cannot be compared with a content analysis in this way C) Certain words may be identical in one language but have multiple forms in another (correct) D) Because German words are generally longer than English words, the number of tokens will be lower than in the English text.”

Procedure

Table 2 shows the detailed course structure. Each of the five lessons covered a topic pertaining to social science research methods, such as survey design or an introduction to statistics and correlation.

Table 2

Design of flipped classroom for 90-minute in-class lessons alongside phases of 5E instructional model

Phase of flipped classroom	Learning activity and duration	Corresponding phase(s) of 5E instructional model	Learning materials / teaching approaches used
Out-of-class	Individual student preparation (1 week)	Engagement, Exploration	Learning materials (texts) with guiding questions
In-class	Instructional video (approx. 15 minutes)	Exploration	Instructional video
In-class	Formative assessment of declarative knowledge with feedback (approx. 20 minutes)	Explanation	Gamified quiz with automated corrective feedback and elaborated feedback by teacher
In-class	Group task with delayed sample solution (approx. 30 minutes)	Elaboration	Cooperative learning, problem-based learning
In-class	Summative educator assessment of individual (domain-specific) application-oriented knowledge (approx. 15 minutes)	Evaluation	Non-gamified quiz

Before each lesson, students completed one week of individual preparation using digitally provided textbook excerpts, illustrations, and guiding questions. The purpose was to support Engagement and Exploration by activating prior knowledge and building a foundation for the in-class activities. Examples of guiding questions include “What is a spurious correlation? Give one example of your own!” and “Pick one of the presented research designs. To what kind of questions within the field of media pedagogy could it be applied?” The in-class segment began with an 11–17-minute instructional video delivered identically in both conditions. Students then completed a gamified formative quiz with immediate automated feedback and additional teacher explanation (approximately 20 minutes). Table 3 shows overall student performance for the quizzes. This concluded *Explanation*.

Students next worked in groups of two to five on a cooperative, problem-based assignment (approximately 30 minutes). Tasks required application of the learning content; for example, one lesson required a comparative type-token ratio analysis. The lecturer then provided and discussed a sample solution. Finally, students completed an individual, non-gamified assessment of

application-oriented knowledge (approximately 15 minutes), followed by delayed feedback. The lesson concluded with the satisfaction rating.

Analysis

For RQ1, independent-samples *t*-tests compared the two modalities on overall DKA, AOKA, SR, ASE, and LS. As we wanted to assess each variable in its own right, Bonferroni correction was not applied. This also served to avoid missing real effects in the naturalistic research setting already affected by situational noise.

For RQ2, a repeated-measures MANCOVA with follow-up univariate tests examined changes across lessons, with modality as a between-subjects factor, time as a within-subject factor, and ASE as a covariate. The dependent variables were DKA, AOKA, and SR. Because the longitudinal sample was reduced due to missing values (n = 40), these results are interpreted cautiously.

For RQ3, a direct-effects path model was estimated in AMOS 29 (N = 101). DKA and ASE were specified as exogenous variables; AOKA, SR, and LS were endogenous variables. The model was informed by the proposed role of DKA as a foundation for AOKA, and by the possibility that ASE relates to SR and LS through self-regulatory processes. The analysis is associational; the longitudinal design does not by itself establish causal direction.

A priori level of significance for all tests was set at $\alpha = .05$.

Results

Rq1: Overall modality differences

Table 3 shows that across the overall measures, the online condition showed lower mean values for DKA, SR, and ASE and higher mean values for AOKA and LS than the face-to-face condition. Only DKA differed significantly: students in the face-to-face condition scored higher (p = .036), with a small to medium effect size (d = 0.429).

Table 3

Mean differences between the students in the online (n = 40) and face-to-face (n = 61) in-class conditions

	Online in-class condition	**Face-to-face in-class condition**	**Result of t-test for equality of means**
Declarative knowledge (gamified quiz)	*M* = 0.51, *SD* = 0.14	*M* = 0.58, *SD* = 0.19	*t*(97.698) = 2.12, *p* = .036; *d* = 0.429
Application-oriented knowledge (non-gamified quiz)	*M* = 0.52, *SD* = 0.15	*M* = 0.51, *SD* = 0.12	*t*(99) = -.39, *p* = .697
Social relatedness	*M* = 2.80, *SD* = 0.91	*M* = 3.07, *SD* = 0.98	*t*(99) = 1.41, *p* = .162
Academic self-efficacy	*M* = 2.71, *SD* = 0.50	*M* = 2.80, *SD* = 0.48	*t*(99) = .90, *p* = .371
Learning satisfaction (overall)	*M* = 7.15, *SD* = 1.46	*M* = 6.88, *SD* = 1.38	*t*(99) = -.95, *p* = .345

Consequently, while the two modalities may not be equivalent, only one advantage for face-to-face delivery was observed, and this was for DKA. Otherwise, the results show broadly similar outcomes with no other statistically significant differences.

Rq2: Longitudinal measures

The repeated-measures analysis used *n* = 40 students because of missing values. The multivariate tests showed a significant interaction between time and modality: Pillai's Trace = 0.50, $F_{(12, 26)} = 2.15$, $p = .050$, $\eta p^2 = .050$. No other significant relationships were found. This means that changes over the five measurements occurred for the dependent variables. However, no universal influence of time or modality was observed. Instead, modality partly explains the changes over the lessons, while the covariate ASE does not explain these differences.

Univariate follow-up analyses showed this interaction to be significant for AOKA ($F_{4, 148} = 2.840$, $p = .026$, $\eta p^2 = .071$). No significant interactions were found for DKA ($p = .616$) or SR ($p = .590$). Pairwise comparisons then showed significant differences between modalities for the fifth lesson (*MD* = 0.11, *SE* = 0.53). This means that individual performances varied greatly during that session. The difference between groups was significant, with the in-class group (*M* = 0.63, *SE* = 0.04) outperforming the online group (*M* = 0.52, *SE* = 0.04) by more than one point on average.

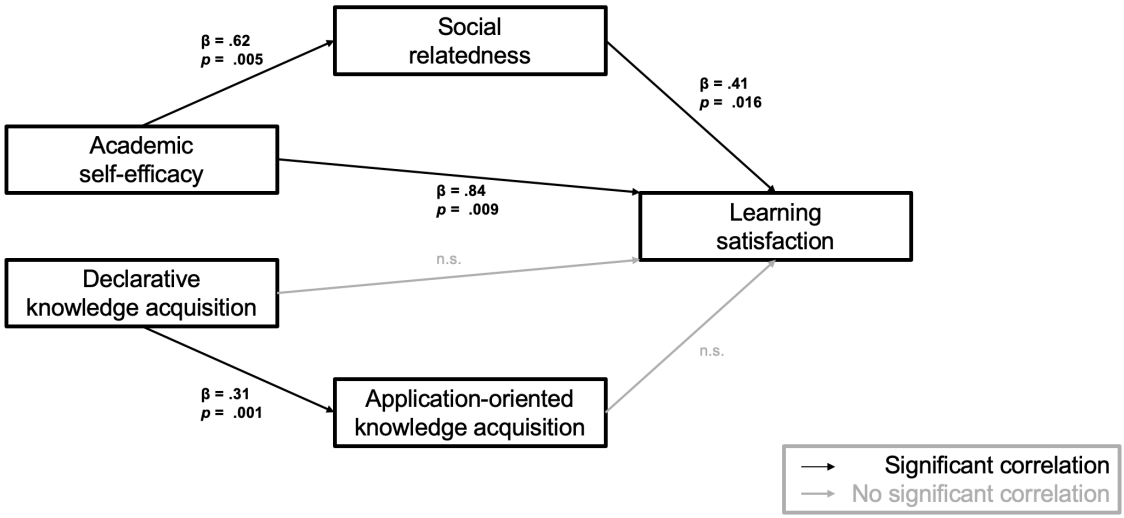
Rq3: Relationships between performance and affect

The final model, shown in Figure 1, had acceptable fit ($\chi^2 = 8.262$, df = 4, CFI = 0.927). While the RMSEA value of .103 suggests bad fit (90% CI [.000, .204], the non-significant pclose value of .157 instead indicates that a good fit is plausible. A possible explanation is that RMSEA is not well suited to models with few degrees of freedom or smaller sample sizes, pointing towards bad fit even if the model fits the data well (Kenny et al., 2015).

As assumed, DKA helped positively predict AOKA (β = .31, *p* = .001). ASE was associated with SR (β = .62, *p* = .005), and SR showed a relationship to LS (β = .41, *p* = .016). An association was also found between ASE and LS (β = .84, *p* = .009).

Figure 1

Direct effects path model



In other words, knowledge acquisition was not associated with LS. Meanwhile, ASE helped explain SR and LS. In turn, SR significantly predicted LS as well. No significant associations between the knowledge measures and the affective variables were detected in the model. These estimates describe the specified model and should not be interpreted as causal effects.

Discussion

The study examined (1) whether a common 5E-informed flipped-classroom design produced different outcomes when its in-class component was delivered online or face-to-face, (2) how outcomes changed across five lessons, and (3) how knowledge and affective variables were related. Three findings are central: First, overall outcomes were broadly similar across modalities, with a statistically significant difference only for DKA. Second, longitudinal patterns varied over time, including a time × modality interaction for AOKA and associations between ASE and both AOKA and LS. Third, the path model separated the achievement and affective processes: DKA predicted AOKA, whereas ASE and SR were associated with LS.

Overall differences between students in online or face-to-face in-class modality

The face-to-face condition showed higher DKA, with *d* = 0.429. The result is compatible with research reporting some advantages for face-to-face learning, but the present design does not establish why the difference occurred. Preparation behaviour, interaction during the video and quiz, and other contextual factors were not measured directly. In addition, caution is merited

regarding the implication that groups meaningfully differed in DKA. Forgoing correction strategies for the number of group comparison tests also resulted in a higher false positive risk. This would further underline the broadly similar results between modalities. In any case, no significant modality differences were detected for AOKA, SR, ASE, or LS. Thus, the study provides evidence that both modalities can be used to implement this particular, 5E-informed flipped sequence in practice, while leaving open whether they are equivalent in a statistical sense. This invites further research on contextual factors.

This performance difference was small and is unlikely to be educationally substantial. Larson et al. (2023) similarly found student performance to be largely consistent regardless of students' chosen modality. They add that offering students a choice between online and partly face-to-face learning may be beneficial. This was also affirmed by some participants' comments to the lecturer during the present study. However, while educational technology can tailor learning to student preferences, observable learning strategies should be prioritised over student preference alone (Hattie & O'Leary, 2025).

The absence of broader modality differences also illustrates why modality should be interpreted together with instructional design. Both groups received the same preparation materials, video instruction, formative feedback, collaborative task, and individual application assessment. The comparison therefore differs from studies in which online and face-to-face courses also differ in pedagogy. Within the limits of this quasi-experimental setting, the instructional sequence appears to account for more of the common learning experience than modality alone.

Longitudinal patterns and academic self-efficacy

The longitudinal findings suggest that student outcomes were not static across the five lessons. The interaction between time and modality for AOKA indicates that application-oriented performance followed a different trajectory than DKA. Because topics varied in content and likely in difficulty, the analysis cannot attribute these trajectories to modality itself. Familiarisation, topic difficulty, or lesson-specific characteristics are plausible explanations that require direct testing. Since the difference arose for AOKA and favoured the in-class condition, it is possible that characteristics of the chosen group task for that lesson were especially conducive for in-class learning. However, performance between students varied widely in places. This observation further underlines that simply choosing a supposedly superior modality is not a sufficient educational strategy. Redesigning lesson 5 and providing additional scaffolding in the form of formative assessment, feedback, or tailored supplementary materials may be fruitful approaches to support students on the lower end of the performance bracket.

Confidence in one's capacity to learn may be particularly relevant when students must regulate their engagement and persist with demanding tasks. However, ASE did not play a role in the interaction between time and modality. In other words, it was not found to be particularly more or less beneficial for either face-to-face or online in-class learning. The practical implication is therefore to consider self-efficacy when designing support for independent preparation and complex application, while avoiding the stronger claim that increasing ASE will necessarily cause higher achievement.

Relationships between performance and affect

The path model provides a useful qualification to interpretations based on student satisfaction alone. DKA predicted AOKA, supporting the idea that declarative knowledge may provide a foundation for later application. In contrast, neither knowledge measure showed a significant association with LS in the specified model. ASE and SR were associated with satisfaction instead. This distinction is consistent with evidence that favourable student evaluations do not necessarily correspond to learning (Uttl et al., 2017). The same applies to ASE and performance (Rafiola et al., 2020). Satisfaction may therefore provide information about students' experience without serving as a direct indicator of cognitive learning. In other words, prior evidence does not support the notion that students who rate a learning situation more favourably necessarily learn more, or vice versa. For example, high learning satisfaction may reflect positive experience without necessarily indicating effortful study. Investigations of learning behaviour may help explain how positive affect may or may not translate into improved cognitive learning outcomes.

Implications for higher education practice

For educators, the study supports using a theory-driven sequence when designing flipped lessons. In particular, pre-class materials can be designed to activate prior knowledge, formative assessment can be paired with elaborated feedback, and class time can be reserved for collaborative application rather than repeated transmission of basic content. The 5E model of instruction can be a suitable guide for designing flipped classrooms in higher education by facilitating the selection of learning activities and their allocation to the various phases of the model.

Meanwhile, the modality comparison does not indicate that moving the in-class component online necessarily changes all measured outcomes. Institutions and instructors can therefore consider accessibility, scheduling, interactional requirements, and student circumstances alongside learning outcomes when selecting a modality. This is a contextual implication, not a claim that the two modalities are equivalent. When choosing concrete learning activities, special consideration should be paid to which elements might be especially suited to face-to-face or online group learning, respectively. Formative assessment may help in uncovering these tendencies to redesign tasks or provide additional scaffolding to help ameliorate differences in students' knowledge acquisition. Feedback and opportunities for successful engagement are plausible design routes, but experimental research is needed before specific self-efficacy interventions can be claimed to improve achievement.

Theoretical implications

The study shows how the 5E model's constructivist logic can be used to make the design choices of a higher education flipped classroom explicit. *Engage* and *Explore* guided preparation and activation of prior knowledge; *Explain* connected formative assessment with elaborated feedback; *Elaborate* created opportunities for collaborative application; and *Evaluate* provided an individual measure of transfer. This mapping addresses a limitation identified in reviews of flipped-learning research: the need to move from descriptions of technology or activity types toward more explicit theoretical rationales for why activities are sequenced the way they are (Baig & Yadegaridehkordi, 2023; Schmid et al., 2023). The findings also suggest that the framework can accommodate both online and face-to-face in-class delivery without requiring a notably different lesson architecture.

Against this background, more specialised frameworks building on the 5E model could be developed for higher education or for specific disciplinary domains.

Limitations and future research

Five limitations are especially important for interpreting the findings. First, students self-selected their modality, so unmeasured pre-existing differences may account for some between-group differences despite the absence of significant differences in prior knowledge and epistemological beliefs. The participant sample was skewed by gender, although no observable effects resulted from this, matching recent evidence in flipped classroom research (Samaila et al., 2026). Nevertheless, other factors may have contributed to group heterogeneity and introduced bias into the analyses.

Second, the study was conducted in one required social science course at one German university with one instructor. Geographical imbalances in flipped classroom research create a need for further investigations across cultural and geographical contexts (Baig & Yadegaridehkordi, 2023; Bredow et al., 2021). Generalisation to other disciplines, institutions, instructors, and student populations is therefore limited.

Third, Bonferroni correction was not applied for RQ1's more exploratory approach to maximise statistical power. However, trying to avoid type II errors in this manner increases the risk of encountering type I errors. Future studies should consider employing better alternatives, such as Holm-Bonferroni correction or Benjamini-Hochberg False Discovery Rate. Fourth, the longitudinal analyses involved a reduced sample and borderline significance, which merit caution in interpreting the time-related effects. Fifth, preparation behaviour was not measured directly, and LS was assessed with a brief single-item rating. More detailed behavioural and affective measures would help identify mechanisms underlying modality and time effects. Finally, the path model is observational and should not be read as establishing causal relationships or mediation.

Future studies should test the 5E-informed design across institutions and disciplines, use randomisation or stronger quasi-experimental controls where feasible, and compare the framework with alternative instructional designs. Repeated measures of preparation behaviour, interaction, and task engagement could clarify why students in different modalities follow different performance trajectories. Further research on the suitability of different group tasks for face-to-face or online learning is also warranted to best support students in either course modality.

Conclusion

This study provides a theory-informed account of a higher education flipped classroom. It was implemented using the 5E instructional model and examined in both fully online and face-to-face in-class conditions. Within this common design, outcomes were broadly similar between modalities, although the face-to-face group showed one significant difference in slightly higher declarative knowledge scores. Longitudinal results indicated that application-oriented knowledge acquisition outcomes changed across lessons. Declarative knowledge also predicted application-oriented knowledge, while satisfaction was significantly related to affective variables, but not to performance. Taken together, the findings support the use of explicit instructional design principles when implementing flipped learning, and caution against treating modality or satisfaction as stand-alone indicators of learning. The study offers a concrete 5E-based design

example while leaving questions of causal mechanisms and broader generalisability for future research.

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