

Effects of flipped learning on secondary students' chemistry achievement and attitudes

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Abstract

This study investigated the effect of flipped learning (FL) on eleventh-grade students' achievement in chemistry and attitudes toward flipping in Jordan. The research design was quasi-experimental, and 157 eleventh-grade students were enrolled in an experimental group (EG) (n = 81) that was instructed through FL and a control group (CG) (n = 76) that was taught via traditional instruction. Data were collected using a researcher-developed achievement test and an attitude questionnaire. Content validity was established through review by subject-matter experts, and the attitude questionnaire demonstrated good internal consistency (Cronbach's alpha = 0.88). It was concluded that the FL model significantly improved students' performance compared to the CG and consequently resulted in improved understanding of chemistry concepts. Furthermore, students in the EG generally demonstrated favorable attitudes toward FL. A statistically significant gender difference was found in students' achievement, with female students outperforming male students in the FL group. However, no statistically significant gender differences were observed in students' attitudes toward FL. In addition, students with lower levels of computer proficiency reported fewer positive perceptions of the FL approach than their peers. In general, the study results indicate that FL can contribute to enhancing science education by promoting engagement and interest in science, as well as motivation toward science and academic performance in science. The research highlights that more research is required on the long-term implications of FL and on how it can be made more accommodating for a variety of learners.

Keywords: achievement, flipped learning, effects, chemistry, attitudes, secondary students

INTRODUCTION

Background of the Study

The rapid changes in information and communication technology have profoundly impacted the education systems at large across the globe, primarily focusing more on student-centered learning with continuous use of technology (Ministry of Education, 2018). These advances are more significant in science education since science is mostly about complex concepts that students struggle to understand and, therefore, when we address these challenges interactive teaching methods must be used (Alsalhi et al., 2019; Bishop & Verleger, 2013). Teachers are, however, exhorted to vary teaching strategies in accordance with contemporary pedagogical trends and changing needs

of learners (Al-Rawajfah, 2019; Bisharat, 2017; Mohamed et al., 2019). In Jordan the aspiratory school system gives chemistry its place as a basic subject. Yet traditional lecture-based teaching methods remain prevalent in chemistry classrooms, which means students have few interactions or exposure to conceptual ingestion and active learning. These barriers have led to common problems, including disengagement, lack of motivation and issues with the comprehension of basic science concepts (Alkhalwaldeh, 2017; Bataineh & Al-Shbatat, 2016). Over the past decades, educational reform movements have increasingly called for fundamental changes in how schools operate and how learning is structured. Rather than focusing solely on incremental improvements, scholars have emphasized the need for more substantial redesign of teaching practices and classroom organization. Jacobs and Alcock (2019), in

Contribution to the literature

- This study explores the use of flipped learning in secondary chemistry education and provides evidence of its impact on students' achievement and attitudes in the Jordanian context.
- It shows how flipped learning can support students' understanding, increase their engagement, and encourage more independent learning.
- The study also highlights the influence of learner-related factors, such as gender and computer literacy, on the effectiveness of flipped learning.

bold moves for schools, argue that meaningful improvement in student learning requires rethinking how instructional time is organized, shifting from content coverage toward deeper conceptual engagement, and integrating technology in ways that actively support learning rather than passive consumption. Within this broader reform context, flipped learning (FL) may be viewed as one practical response to such calls for instructional transformation (Jacobs & Alcock, 2019). By reorganizing when direct instruction occurs and allocating classroom time to dialogue, inquiry, and application, FL aligns with contemporary efforts to redesign learning environments around active student participation.

Research Gap

In spite of the increasing global uptake and implementation of FL, and growing interest in this approach for chemistry education in Jordan, empirical evidence regarding the effectiveness of FL is scarce among both secondary (high) school students. Many of the studies in the region were of a descriptive research design or only concentrated more on overall attitudes toward digital learning rather than success achieved per particular subject (Díaz-Rico, 2014). In addition, because the majority of investigations in Arab contexts have focused on FL within higher education where prevalence among participants is also limited a need exists to explore its feasibility and effectiveness when integrated into school-based chemistry learning. A second important omission is learner factors. Although constructivist theory emphasizes learner attributes, such as prior knowledge, motivation and digital competence (Lim et al., 2019; Little, 2015), little is understood in regional contexts about how students' computer literacy may influence the success of FL. This is especially important as FL is designed for students to access and learn from pre-class materials and educational technologies on their own. There has also been little research in Jordan that examines the relationship between gender and the FL context. A few studies have reported on gender differences in overall science achievement, but whether male and female students share equally in learning from the FL approach in chemistry is not well-documented. Collectively, these voids indicate the need for systematic exploration of FL model in Jordanian secondary chemistry classrooms and

especially regarding learners' variables like gender and computer literacy.

Purpose of the Study

The current study aims to investigate the outcomes of FL on eleventh-grade students in Jordanian public schools in terms of their academic achievement and attitudes towards chemistry. More specifically, the investigation aims to determine whether FL model can promote students' conceptual understanding of chemistry topics in comparison with traditional teaching. Furthermore, the study hopes to investigate the degree and manner in which factors at learner level specifically gender and computer literacy may moderate students' reactions against FL. However, this study also aims to explore how students perceive their experiences with pre-class learning activities (e.g., video-based instruction) and in-class collaborative inquiry-based activities, as grounded in constructivist theory. With a consideration of achievement measures, attitude surveys and learner types, the study offers a detailed assessment of how FL operates in the secondary chemistry context in Jordan. In general, it is hoped that the research will contribute to filling the gaps in literature and provide empirical data on the pedagogical potential of FL and its differentiated effects on student groups.

Research Questions

The study was guided by the following research questions (RQs):

- RQ1.** To what extent does the FL approach improve secondary students' academic achievement in chemistry compared to traditional instruction?
- RQ2.** Are there statistically significant differences in chemistry achievement between male and female students within the experimental (FL) group?
- RQ3.** How do students in the experimental group (EG) perceive the use of FL in chemistry instruction?
- RQ4.** How do students' gender and computer literacy levels influence their attitudes toward FL?

THEORETICAL FRAMEWORK

This study is informed by constructivism, which posits that learners are active constructors of their knowledge through interaction, reflection, and involvement in authentic tasks (Bransford et al., 2000). In constructivist theory, knowledge is not simply transmitted from teacher to student; rather, learning occurs as individuals actively form connections between new and previous experiences and existing conceptions.

Piaget's (1970) Cognitive Constructivism

Constructivist theory, as developed through the works of Piaget (1970) and later enriched by Vygotsky's (1978) social perspective is grounded in the fundamental assumption that learners actively construct knowledge through cognitive engagement and social interaction. In this sense, students are better learners when they work autonomously, manipulate their environment, and engage in meaningful problem-solving tasks (Ahmad et al., 2016; Piaget, 1970). As a result, cognitive processing and the restructuring of knowledge are considered central mechanisms of learning within Piagetian theory (Fosnot, 2013; Schunk, 2012). FL can be viewed as an instructional approach that aligns closely with the core assumptions of constructivist theory. By transferring initial exposure to new content outside the classroom, often through teacher-prepared videos or digital materials, students are provided with opportunities to engage with concepts at their own pace and according to their individual readiness. This flexibility supports learner autonomy and encourages active cognitive engagement prior to formal classroom interaction. Class time can then be devoted to higher-order tasks such as discussion, problem-solving, clarification of misconceptions, and guided inquiry. Such use of instructional time allows learners to refine and reorganize their understanding through meaningful interaction and feedback. From a Piagetian perspective, these processes reflect mechanisms of assimilation and accommodation, whereby learners actively restructure their cognitive schemas in response to new experiences (Piaget, 1970). Empirical research on FL further suggests that this model enhances conceptual understanding, promotes deeper processing of subject matter, and increases student engagement when compared to traditional lecture-based instruction (Akçayır & Akçayır, 2018; Bishop & Verleger, 2013; Zainuddin & Halili, 2016). Accordingly, FL may be interpreted not merely as a technological innovation, but as a pedagogical model grounded in constructivist principles.

Vygotsky's (1978) Social Constructivism

Vygotsky (1978) highlighted the fundamental role of social interaction and cultural mediation in the development of higher cognitive functions. Central to

his theory is the concept of the zone of proximal development (ZPD), which describes the range of tasks learners cannot yet perform independently but can accomplish with appropriate guidance. Learning, from this perspective, is not an isolated mental process but a socially mediated activity shaped by dialogue, collaboration, and structured support. The idea of scaffolding, later articulated by Wood et al. (1976), further explains how temporary instructional support enables learners to gradually assume greater responsibility for their own understanding. Through guided questioning, feedback, and collaborative engagement, learners internalize strategies that eventually become part of their independent cognitive repertoire. These theoretical principles resonate strongly with FL environments. When direct instruction is moved outside the classroom, instructional time can be reallocated to peer discussion, collaborative inquiry, and teacher-facilitated clarification. Such settings create opportunities for learners to articulate their reasoning, confront misconceptions, and construct shared understanding within their ZPD. Moreover, digital materials accessed before class may function as mediational tools that prepare students cognitively for deeper social interaction during in-class activities (Lo & Hew, 2017). In this sense, FL can be interpreted not merely as a change in instructional sequence, but as a pedagogical structure consistent with Vygotskian social constructivism.

Flipped Learning: A Constructivist Model of Education

FL can be understood as an instructional approach that naturally reflects both cognitive and social constructivist assumptions. When students are introduced to new content before class, they begin to form initial understandings independently. This early engagement allows them to activate prior knowledge and start reorganizing their ideas, a process that aligns with Piaget's (1970) view of learning as active cognitive construction. Once students come to class, the focus shifts from receiving information to working with it. Through discussion, collaborative tasks, and guided questioning, learners are encouraged to explain their reasoning, challenge their assumptions, and refine their understanding. These classroom interactions resonate with Vygotsky's (1978) emphasis on social mediation and the importance of dialogue in advancing thinking. In addition, the flipped model places greater responsibility on learners. Because students must prepare before class, they gradually develop stronger self-regulation skills and a sense of ownership over their learning. The use of digital and multimedia materials also offers flexibility, allowing students to engage with content at their own pace and revisit explanations when needed. Such flexibility can be especially valuable in subjects like chemistry, where abstract ideas often

require repeated exposure and reflection. More broadly, this orientation is consistent with ongoing discussions about restructuring instructional time in ways that prioritize deeper engagement rather than passive content delivery (Alarab et al., 2023; Fullan & Langworthy, 2014; Hattie, 2009). Within this framework, FL is not merely a technical adjustment to lesson sequencing, but a pedagogical choice grounded in constructivist principles. The present study therefore examines the effectiveness of this approach in the context of secondary chemistry education.

The Conceptual Framework for the Study

Based on the constructivist perspective, we take as our point of departure for this study:

- Pre-class video instruction helps to provide students with an opportunity for initial comprehension and cognitive processing.
- Throughout the lesson, groups are engaging in collaborative activities where learning is being reinforced through interaction and scaffolded support.
- Learner factors in terms of gender and computer proficiency, also can have its impact on students' learning when engaging with FL activities.

Therefore, FL is categorized as the independent variable in this study and its impact on students' chemistry achievement and attitudes will be evaluated, which are in turn treated as dependent variables we can intervene with to enhance learning experience (e.g., O'Flaherty & Phillips, 2015). The potential moderators (i.e., gender and computer literacy) that may impact on the efficacy of such pedagogical approach were also considered.

Drawing on the constructivist perspectives discussed in the previous sections, the present study proposes a conceptual framework that links both cognitive and social constructivist ideas to the FL model. Within this framework, FL is viewed as an instructional approach that encourages active participation and meaningful interaction, creating conditions that support important learning processes (Al-Harthy et al., 2010). These processes are expected to contribute to students' academic achievement, deeper conceptual understanding, and greater engagement in learning, particularly in the context of secondary chemistry education. The relationships among these elements are summarized in the conceptual framework presented in **Figure 1**.

Flipped Learning

FL becomes a promising teaching approach which changes the order of traditional teaching sequence (Abeysekera & Dawson, 2015). In this model, students are initially introduced to new material outside of class

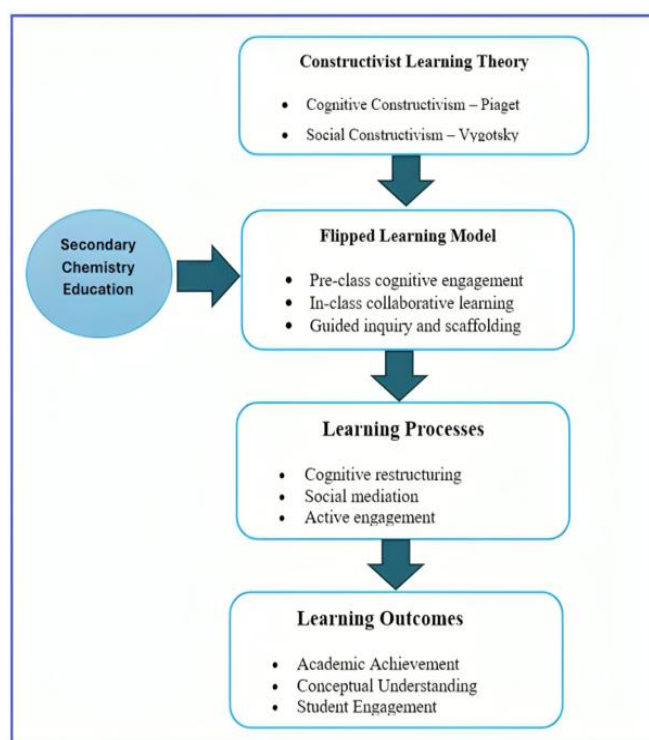


Figure 1. Conceptual framework illustrating the relationships among constructivist learning theory, the flipped learning model, and learning outcomes in secondary chemistry education (Piaget, 1970; Vygotsky, 1978)

often through teacher-generated videos or digital resources and use in-class time for higher-order activities like questioning, discussion, problem solving and application of learning (Bishop & Verleger, 2013). This reorganization allows teachers to provide more personal assistance during lessons and students can progress at their own pace. Research in the domain of STEM disciplines demonstrate that FL is more effective than traditional mode of teaching for enhancing learner' achievement, conceptual understanding, and motivation (Gong et al., 2024; Schultz et al., 2014; Su & Chen, 2018). In chemistry education, FL has also been shown to increase student engagement and help students understand difficult scientific concepts through multimedia explanations and active learning activities (Seery, 2015).

To emphasize the pedagogical differences and similarities between these two learning paradigms, **Table 1** provides a comparison of traditional instruction with FL, in terms of the role played by teachers, students' needs for control over their own learning experience, and the importance that is placed upon new technologies.

Following this comparison, **Figure 2** provides a conceptual overview of the key features and educational benefits commonly associated with the FL model. This visual representation helps clarify how the approach fosters active engagement, supports differentiated learning, and promotes deeper cognitive processing.

Table 1. Comparison between FL and conventional education (Bergmann & Sams, 2012; Bishop & Verleger, 2013).

Features	Conventional education	FL
Teacher role	The teacher explains the topics of the book’s content in the classroom.	The teacher sends video clips and interactive activities related to the educational content before the class through the presentation platforms, after which the pupils discuss what they saw inside the classroom.
Student role	The student is a recipient of information and knowledge	The student needs to actively seek out information and participate in knowledge-building activities.
Using modern technologies	The use of contemporary technologies is not encouraged	Stimulates and encourages the use of modern technologies

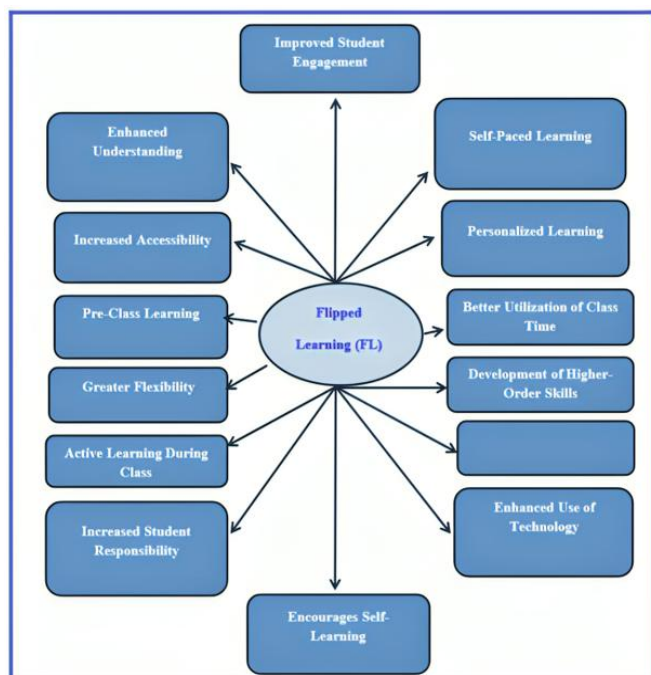


Figure 2. Features and benefits of FL (Source: Author’s own elaboration)

METHODOLOGY

Research Design

This was a quasi-experimental pre-/post-test non-equivalent groups design, one of the designs typically utilized in natural classroom settings where random assignment is not feasible (Creswell & Clark, 2011). Two eleventh-grade chemistry standard classes of a public school were chosen for the study: one of the groups was then used as an EG and received teaching through FL, while the other served as a control group (CG) and was taught by traditional, front-based method. Both pre-test groups administered a pre-test before intervention to ensure the equivalence of baseline.

Both groups underwent the post-test after six weeks of teaching based on comparison of learning achievements of each group due to the method. Students in the EG also took a computer literacy scale test, which put students in four levels of proficiency. This enabled the study to test if computer skills could moderate FL students’ achievement and attitudes. In order to visualize the flow of procedures (i.e., from pre-testing

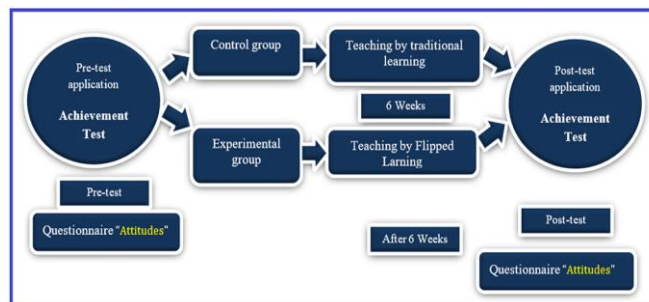


Figure 3. Design of the study (Alsalmi et al., 2019)

Table 2. Teaching topics in the unit shapes of molecules and intermolecular forces

Unit name	Topics	Pages
Shapes of molecules and intermolecular forces	Lesson 1. VSEPR	9-23
	Lesson 2. Bonds and overlapped orbitals	24-35
	Lesson 3. Intermolecular forces	36-47

via instructional intervention to post-test) the design of study is depicted in **Figure 3**.

Table 2 presents the teaching topics included in the unit “shapes of molecules and intermolecular forces.” The page numbers shown in **Table 2** refer to the corresponding pages in the chemistry textbook used in the study.

Participants

The study sample consisted of two intact eleventh-grade chemistry classes (N = 157), selected through purposive sampling in coordination with the school administration. One class was assigned as the EG (n = 81), and the other as the CG (n = 76). The participants were similar in age, educational background, and prior exposure to chemistry instruction. Gender distribution was recorded to analyze its moderating effect in the FL context. Participation was voluntary, and students were informed that their academic standing would not be affected by the study.

Table 3 summarizes the distribution of students across experimental and CGs.

Table 4 presents additional demographic information related to gender and computer literacy levels within the EG.

Table 3. Details about the participants' demographics

Group	Frequency (f)	Learning approach
EG	81	FL
CG	76	Conventional education
Total	157	

Table 4. Demographic characteristics of participants in EG and CG

Variables	Category	EG (n = 81)	CG (n = 76)
Gender	Male	42 (51.9%)	39 (51.3%)
	Female	39 (48.1%)	37 (48.7%)
	Total	81 (100%)	76 (100%)
Computer skills	Excellent	16 (19.8%)	14 (18.4%)
	Very good	22 (27.2%)	20 (26.3%)
	Good	29 (35.8%)	27 (35.5%)
	Weak	14 (17.3%)	15 (19.7%)
	Total	81 (100%)	76 (100%)

Instructional Materials

The teaching material was under the chemistry group unit "shapes of molecules and intermolecular forces" present in the national curriculum. Topics and pages comprising the unit are listed in **Table 2**.

Table 2 presents the teaching topics included in the instructional unit "shapes of molecules and intermolecular forces." The page numbers refer to the corresponding pages in the chemistry textbook used during the implementation of the lessons.

Flipped learning resources included teacher generated videos, slides and interactive activities posted on the school's platform for students to view before lessons. Students' in-class assignments involved problem-solving, cooperative learning, directed inquiry and peer discussion. The CG learned the same content from a comparable curriculum, but in teacher-centered lectures and textbook explanations.

Instruments

This study relied on four main instruments.

Educational material (flipped learning package)

Flipped instructions with the instruction materials created by the researcher, together with some teaching teachers who have taught chemistry at many levels. These materials were connected with the topic "shapes of molecules and intermolecular forces" and developed to encourage students' self-directed out-of-class learning as well as in-class participative activities.

Materials included:

- pre-recorded instructional videos
- interactive slides and digital activities
- animations and simulations
- printable worksheets
- a structured teacher's guide
- links to additional multimedia resources

Everything was posted in Google Classroom, our main content-delivery platform. Some videos came to students via a private YouTube channel as well as on the school's Blackboard system. Example of pre-class video content ranged from:

- <https://youtu.be/9YwdeEDrfPI>
- <https://youtu.be/pBZ-RiT5nEE>

Students were assigned to watch lecture materials before class and complete short preparatory mini-tasks, such as brief conceptual questions and simple problem-solving exercises, designed to prepare them for in-class learning activities. An illustration from the video collection used is presented in **Figure 4**.

The design of the materials was informed by previous FL frameworks (e.g., Akçayır & Akçayır, 2018; Zainuddin & Halili, 2016) and aligned with the national chemistry curriculum.

Chemistry achievement test

A chemistry achievement test was developed by the researcher to evaluate students' comprehension of the eleventh-grade unit "shapes of molecules and

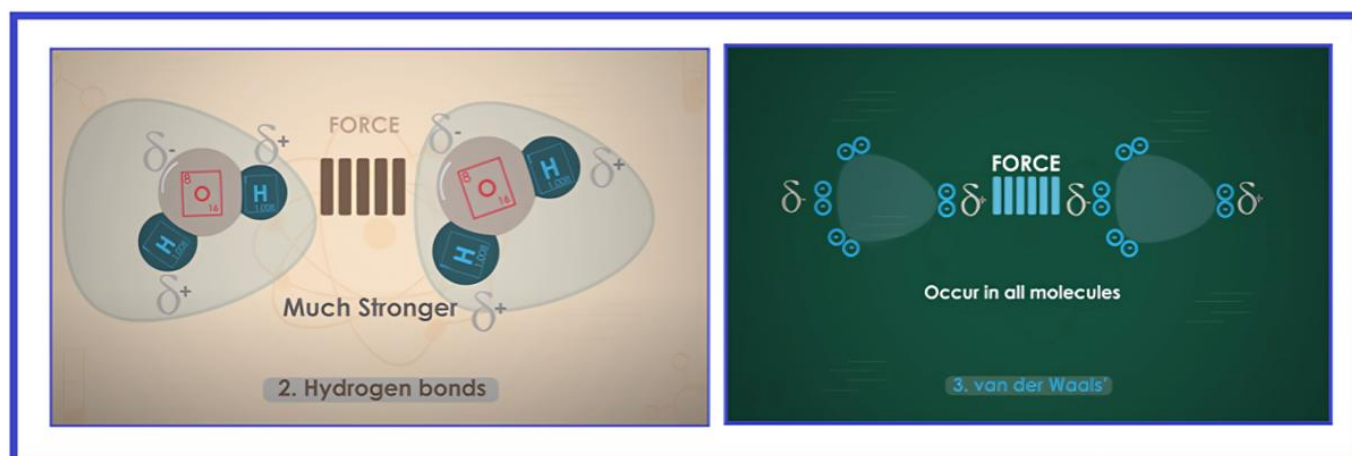


Figure 4. The eleventh-grade chemistry textbook's motion unit platform (FuseSchool, 2016)

intermolecular forces" in the national curriculum. The test was based on three content domains: Valence-Shell electron-pair repulsion theory (VSEPR), bonds and overlapped orbitals, and intermolecular forces. The test items were constructed to represent a continuum of cognitive demand and some items fell into the categories of simple recall as well as application, analysis, and evaluation. Clarity, relevance to content coverage and the validity of the items were assured by having a panel of experience chemistry teachers review them for appropriateness. The measure was determined at two timepoints:

- Pre-test: employed to detect differences between the experimental and CGs prior to FL implementation.
- Post-test: developed to measure the effect of the intervention on students' learning outcomes.

Item difficulty and discrimination scores were obtained following testing the test. Poorly functioning items were modified or substituted, and the overall reliability of the instrument was tested with Cronbach's alpha. In order to demonstrate the diversity and cognitive complexity of the items that were included in the test, a few examples are listed below:

Remembering: Which of the following molecules has a tetrahedral shape?

- a. CO₂
- b. CH₄
- c. H₂O
- d. NH₃

Understanding: Why does the water molecule have a bent molecular shape?

- a. Because of double bonds
- b. Because of lone pairs on oxygen
- c. Because of hydrogen bonding
- d. Due to resonance

Applying: Which type of intermolecular force is most common in HCl?

- a. Ionic
- b. Dipole-dipole
- c. London dispersion
- d. Metallic bonding

Analyzing: H₂O has a much higher boiling point than CH₄. What best explains this?

- a. Molar mass
- b. Covalent bonding
- c. Hydrogen bonding
- d. Atomic radius

Evaluating: Which of the following Lewis structures is least likely to exist based on formal charge?

- a. NO₂⁻

- b. O₃
- c. H₃O⁺
- d. CO

Creating: Which group of atoms could form a trigonal-planar molecule with no net dipole moment?

- a. C, H, H, H
- b. B, F, F, F
- c. N, H, H, H
- d. O, H, H, H

These types show the organization of a whole test in that this tool considered all basic and thinking skills from chemistry unit.

Validity and reliability of the achievement test

It was important to have a high-quality achievement test in order to validly reflect students' understanding of the chemistry unit. Hence, measures were taken to establish its validity and reliability.

Content validity: The original form of the test was validated through a panel review by ten university faculty members in science education and educational technology. They reviewed each item for clarity, the extent to which it was aligned with the unit's learning objectives, and its suitability for students in eleventh-grade. Reviewers' feedback led to the clarification of item wording and balancing of cognitive levels in order for the test to thoroughly reflect the chemistry content of interest.

Pilot testing and item analysis: A 15-person pilot study was carried out on students from a neighboring school that were not included in the main study. The responses were checked for item difficulty and discrimination. Easy items, hard items or those without high/low score spread were modified or discarded. This ensured that the psychometric properties of the test were robust before full implementation.

Reliability: To test the reliability, the same pilot group was tested twice with a two-week interval (test-retest method). The Pearson correlation coefficient for this was 0.84, which suggested good stability and internal consistency. This demonstrates that the test is reliable when applied in similar circumstances.

The attitude toward flipped learning scale

Description of the instrument: Researcher-designed questionnaires were applied to assess students' attitudes towards the FL model. It was applied to the 81 students in the EG and was composed of 20 items that measured different dimensions represented by four factors: perceived effectiveness of FL, motivation to learn, classroom interaction, and ease of using digital platforms. The items were based on previous literature of FL and SE (Akçayır & Akçayır, 2018; Zainuddin & Halili, 2016). Students replied on a five-point Likert

scale from 1 (strongly disagree) to 5 (strongly agree). Examples of the items include: the video lessons helped me to understand concepts in chemistry and FL made me more engaged during lessons.

Content validity: Alqahtani et al. (2023) emphasized the importance of establishing content validity when developing and validating instruments used to measure students' learning experiences in flipped classroom environments. In this study, content validity was established through expert review by ten university faculty members specializing in science education and educational measurement. Their evaluations addressed the clarity of wording, the relevance of items to the study objectives, and the conceptual alignment with FL constructs. Based on their recommendations, several items were refined to enhance accuracy and clarity.

Pilot testing and reliability: A pilot study was conducted with 30 students who were not part of the main sample. The pilot helped evaluate item clarity and initial psychometric properties. Internal consistency reliability was assessed using Cronbach's alpha, yielding: $\alpha = 0.88$, which exceeds the commonly accepted threshold of 0.70, indicating strong internal consistency (Creswell, 2012; Fraenkel et al., 2019).

Computer literacy scale

To examine whether computer proficiency moderates the impact of FL, a computer literacy scale was administered to students in the EG. The scale measured three domains: Basic operational skills (e.g., mouse use, keyboarding, and browser navigation), digital communication and online learning skills, technical problem-solving skills. Students were classified into four proficiency levels: excellent, very good, good, and weak. This classification enabled the researcher to investigate whether computer literacy influenced: students' engagement with pre-class digital materials, their participation in FL activities, or their achievement outcomes. The scale demonstrated strong reliability and was considered appropriate for the technological context of Jordanian secondary schools.

Ethical Considerations and Approval, Availability of Participants

Official ethical clearance to conduct the study was received from the Directorate of Supervision and Educational Development, Ministry of Education based on national research protocols. The school principal had given permission for the classes involved, and all necessary institutional requirements were fulfilled before data collection. To maintain ethical standards, the researcher shared with all students participating in the study the purpose of involvement, procedures to be performed and their rights as participants. Eligible students were explicitly told that participation was voluntary and declining would not prejudice their

academic standing or relationship with the school or their teachers in any way. All participants provided written informed consent. The researcher assured the participants anonymity and confidentiality during and after the study. Student identities were encoded in order to protect against possible identity breach and there was no personal information in the data. None of the study factors had any effect on academic grades, class performance, and teacher evaluations. The collected data were solely utilized for academic research, not shared with schools' directors, or other parties.

Procedures

The data presented here were collected over a duration of six weeks during the first semester of 2023-2024. The treatment was three 45-minute lessons a week of chemistry classes that were based on the official eleventh-grade chemistry curriculum unit "shapes of molecules and intermolecular forces." The same content, learning objectives and instructional time was used for the experimental and control conditions. In order to avoid intra-teacher variability and guarantee teaching congruences, the complete instruction process was undertaken by the same chemistry teacher who had been previously trained following a structured program of training before starting with the experiment. The teachers guide, designed by the VL researcher, contained scripted lesson plans, assessment forms and a detailed procedural manual to ensure consistency in implementation of the FL approach at EG.

Implementation in the intervention group

Experimental students were exposed to FL by means of an organized series of digital and classroom activities. Preparation for each lesson was expected in the form of pre-class materials such as video lectures, interactive slides and brief online quizzes posted on Google Classroom and the school's Blackboard site. These resources were created to promote self-learning and exploration of new material by students at their own pace. During instruction, students completed active learning exercises according to the following categories: guided discussions, collaborative problem-solving, hands-on activities, and application-based exercises. Notes were provided to students for video watching, note taking, reflection and active participation in peer learning activities. They integrated real-life examples; asked questions of their own, and they critiqued video content in lessons fostering student ownership of learning and deeper engagement with the material.

Control group application

The CG was taught using traditional instruction (teacher-led lectures, textbook-based explanations, and whole-class question-and-answer sessions). The CG did not receive face-to-face preparatory sessions prior to

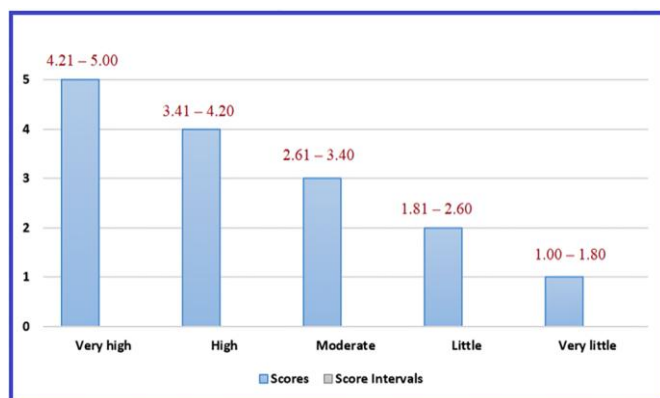


Figure 5. Scale and score interval choices are used to evaluate scale data (Source: Authors’ own elaboration)

class. All teaching was traditional lecture-based, and classroom time was spent reviewing textbook material and practicing routine problems.

Teacher training and preparation

The participating teacher underwent a professional development session led by the investigator before commencing the intervention. The training covered: theorizing in FL, strategies for facilitating student-centered learning, methods for integrating multimedia content, in-class collaborative task processes, and strategies for giving virtual feedback in a timely manner. This practice ensured that the teacher was able to use the flipped model accurately and confidently.

Ethical follow-up

In the interest of ethical considerations, all participants had access to course materials upon completion of the study. This guaranteed that none of the participants was at a disadvantage, and that all students could take advantage of the digital resources created for the intervention.

Statistical Treatment

Statistical analyses were performed through SPSS (version 30). To answer the research questions, descriptive and inferential statistical analyses were used. Mean (M) and standard deviation (SD) were calculated on the basis of descriptive statistics for cases and controls. For inferential analysis, the independent samples t-test was used to determine differences between groups in post-test scores and then to compare males and females within EG. The differences in students’ attitudes towards the environment among

Table 5. M and SD of the two groups’ pre-test results

Group	Frequency (f)	M	SD
EG	81	11.77	1.91
CG	76	11.83	1.59

levels of computer literacy were found with one-way ANOVA where necessary. The magnitude of significant differences was assessed with effect sizes (Cohen’s d), according to the benchmarks suggested by Cohen (1988) as well as to offer the practical significance. Statistical significance tests were all conducted with a confidence level of $\alpha = 0.05$.

Metrics for Analyzing Data

To describe the student attitudes over FL, five-point Likert scale was used in terms of the following: very high (5), high (4), moderate (3), little (2), and very little (1). The interval ranges were determined to categorize responses into respective categories (Figure 5).

RESULTS

Pre-Test Results

Prior to using the FL model, a pre-test was administered to both experimental and CGs in order to assess their initial level of academic achievement in chemistry. The content of the test was related to the subjects treated in the unit. Results For comparison between groups, student’s t-test has been used to determine whether the difference found is statistically significant. The average scores of the two groups were nearly same, as reported in Table 5. Results of the inferential analysis shown in Table 6 reveal that there is no statistically-significant difference between the two groups ($p = .821$), and they had the same former knowledge before the intervention.

Results Related to RQ1

RQ1. To what extent does the FL approach improve secondary students’ academic achievement in chemistry compared to traditional instruction?

In order to do so, an independent-samples t-test was performed in order to compare the post-test scores of the EG (students taught using the FL model) and the CG (students whose instruction was delivered through traditional teaching). As can be seen in Table 7 and Table 8, the average scores for students with EG were significantly higher ($M = 17.47$, $SD = 1.61$) than their control ($M = 15.76$, $SD = 2.10$). t-test showed the

Table 6. t-test findings from the preliminary exam comparing the CG and EG, respectively

	Levene’s test for equality of variances		t-test			
	F	Sig.	t	df	Sig. (2-tailed)	Mean difference
Equal variances assumed	1.185	0.278	0.227	155.000	0.821	0.0635
Equal variances not assumed			0.225	146.176	0.822	0.0635

Note. *Statistically significant at $p \leq 0.05$

Table 7. M and SD of the two groups' post-test results

Group	Frequency (f)	M	SD
EG	81	17.47	1.61
CG	76	15.76	2.10

Table 9. t-test results for EG pupils based on their achievement in chemistry according to the gender variable

Gender	Frequency (f)	M	SD	Standard error mean
Male	42	17.40	1.65	0.2552
Female	39	18.03	1.42	0.2279

comparison to be statistically significant, $t(155) = 5.745$, $p < .001$. These results indicate that the FL model led to a significant increase in students' academic performance in "shapes of molecules and intermolecular forces." The fact that the post-test scores of the EG were higher than those of the CG showed a significant improvement in chemistry learning based on FL.

Results Related to RQ2

RQ2. Are there statistically significant differences in chemistry achievement between male and female students within the experimental (FL) group?

Previous research has reported mixed findings regarding gender differences in reasoning abilities and academic performance across academic domains (Benbow & Stanley, 1996). Therefore, the present study examined whether differences exist between male and female students within the EG. **Table 9** and **Table 10** present the comparison of post-test achievement scores between male and female students in the EG. As shown in **Table 9**, female students obtained a higher M score ($M = 18.03$, $SD = 1.42$) than male students ($M = 17.40$, $SD = 1.65$). The independent samples t-test results presented in **Table 10** indicate that this difference was statistically significant ($t = 1.805$, $p = 0.037$). This finding suggests that female students in the FL group achieved significantly higher scores in chemistry than their male counterparts.

Table 8. t-test findings of post-test

	Levene's test for equality of variances		t-test			
	F	Sig.	t	df	Sig.	Mean difference
Equal variances assumed	2.385	0.125	5.745	155.000	0.000	1.7060
Equal variances not assumed			5.697	140.377	0.000	1.7060

Table 10. t-test findings of post-test

	Levene's test for equality of variances		t-test			
	F	Sig.	t	df	Sig.	Mean difference
Equal variances assumed	0.162	0.688	1.805	79.000	0.037	0.6209
Equal variances not assumed			1.815	78.563	0.037	0.6209

Table 11. Findings of a paired samples t-test

Experiment	Frequency (f)	M	SD	t	df	Sig.
Post-application	81	3.430	0.580	36.914	80	0.000
Pre-application	81	2.160	0.535			

About the Results of RQ3

The students' attitudes towards FL were assessed before and after the intervention to identify differences in their perceptions of active learning methodology.

RQ3. How do students in the EG perceive the use of FL in chemistry instruction?

As a second step, to compare the attitude scores of the students in the implementation process of the FL model before and after, a paired sample t-test was used. The findings of **Table 11** indicate that the attitude of students to FL was significantly enhanced. The average score went from $M = 2.16$ pre-intervention to $M = 3.43$ post-intervention. The average score increased from $M = 2.16$ before the intervention to $M = 3.43$ after the intervention, $t(80) = 36.914$, $p < .001$. This measurable enhancement implies students' change of perceptions toward FL to be more positive after knowing the approach. Collectively, students found the FL approach useful and enjoyable, in particular for learning difficult chemistry concepts. The learning platform that obliged students to read in preparation for class and engage more actively during classes might have led to a better (deeper) understanding and more active cooperation in the classroom. These findings are consistent with other research reports indicating that flipped instruction may enhance students' skills of self-regulation, motivation, and general beliefs in science education (Akçayır & Akçayır, 2018; Kurt, 2022; Lo & Hew, 2017). The observed enhancement in learning could have been driven by documented pedagogical benefits of the model, including more time for self-paced work, media-reinforced instruction and a transition from teacher-centered to more interactive student-centered instruction. As also emphasized by Zainuddin and Halili (2016), such features further provide students with increased capabilities to process content more efficiently and stimulate a higher quality peer interaction during classroom activities.

Table 12. M and SD of the responses provided by the pupils, sorted by gender

Gender	Frequency (f)	M	SD	t	Sig.
Male	36	3.428	0.501	0.015	0.494
Female	45	3.426	0.642		

Table 13. One-way ANOVA results for students' academic performance across computer skills levels

		Sum of squares	df	Mean square	F	Sig.
Student academic performance in science subject	Between groups	4.191	3	1.397	4.731	0.004
	Within groups	22.735	77	0.295		
	Total	26.926	80			

Table 14. Results of the Scheffé exam with reference to the variable computer abilities of pupils being taught chemistry topics

Computer skills (I)	Computer skills (J)	Mean difference (I-J)	Sig.
Excellent	Very good	-0.42935	0.142
	Good	-0.46190	0.068
	Weak	-.66724*	0.006
Very good	Excellent	0.42935	0.142
	Good	-0.03255	0.998
	Weak	-0.23789	0.612
Good	Excellent	0.46190	0.068
	Very good	0.03255	0.998
	Weak	-0.20534	0.668
Weak	Excellent	.66724*	0.006
	Very good	0.23789	0.612
	Good	0.20534	0.668

About the Results of RQ4

RQ4. How do students' gender and computer literacy levels influence their attitudes toward FL?

Two factors were considered in the experiment group: gender and computer literacy.

Gender variable

Independent t-tests were conducted to examine whether there was a gender gap in students' attitudes toward the flipped model. The sample statistics presented in **Table 12** indicate that, on average, males ($M = 3.428$, $SD = 0.501$) scored essentially the same as females ($M = 3.428$; $SD = .501$). The t-test ($t = 0.015$, $p = 0.494$) reveals that there was no significant difference between male and female learners' attitude towards FL. This indicated that male and female students interpreted FL in the same way, and gender did not affect their attitudes toward the flipped approach.

Computer skills variable

To see whether students' attitudes toward FL are different in the computer proficiency groups (excellent, very good, good, and weak), a one-way ANOVA was performed. **Table 13** demonstrated that there were significant differences between groups ($F = 4.731$, $p = 0.004$), which meant computer skill showed different extent of attitudes toward FL. Scheffé post-hoc test was

used to determine which groups had significant differences (**Table 14**). The results revealed that:

- There was a significant difference between those rated weak in computer knowledge and the highest rated group (mean difference = -0.66724 , $p = 0.006$).
- There were no statistically significant differences between any other adjacent group combinations (i.e., excellent vs. very good and very good vs. good).

These results show that students who are not highly proficient in using computers expressed weaker attitudes toward FL than those with high proficiency. The obstacles that some students encountered in finding their way around the digital spaces, finding video resources and successfully completing tasks online-central features of a flipped classroom approach.

The results also suggest that gender was not a significant variable in students' attitudes for the FL, because there were no significantly meaningful differences between male and female students ($p > .05$). But computer literacy was a significant factor ($p < .05$), and the negative tendency was even stronger among those participants who had lower digital competence; such low-skills students showed a significantly less positive attitude to FL ($p < .05$). These findings highlight a need to offer technological support and training for students with lower computer proficiency, so as to facilitate their full participation in and take advantages of FL.

DISCUSSION

The overall conclusions derived from this study strongly suggest that the FL model can be an effective instructional method for improving secondary students' achievement and attitudes in chemistry in Jordan. In general, students who were exposed to FL performed significantly better at post-test than those who received traditional instruction. The enhancement cited above indicates how this FL design (with its pre-class video preparation and guided practice and more in class HOPS time) leads to deep conceptual processing, which makes it possible for students to make sense of some of chemistry's most abstract ideas. These results are consistent with a broad body of research supporting the

conclusion that FL boosts comprehension by engaging students actively, providing multimodal representations, and increasing exposure to instruction (Akçayır & Akçayır, 2018; Alqawasmi et al., 2023; Alzahrani & Alqurashi, 2023; Eltahir & Alsalhi, 2025; Mason et al., 2013). Of significance, this research provides new knowledge from the Jordanian culture where empirical data in FL of secondary chemistry is scarce. Continued gains in achievement as seen here suggest that FL can be used to mitigate issues commonly cited in national reports regarding students' struggles with learning molecular geometry and intermolecular forces. The well-designed digital resources, teacher facilitation support, and deliberate linking of videos to curriculum could have been instrumental in making the advanced microscopic ideas more accessible. Although the achievement gains were statistically significant, the findings on gender need to be interpreted cautiously. Female students achieved significantly higher scores than male students; however, no significant gender differences were observed in students' attitudes toward FL. This is somewhat consistent with previous literature indicating that female students may have higher levels of self-regulation and task engagement in class settings (Wang & Eccles, 2012). However, the lack of attitudinal differences challenges assumptions often cited in regional studies and indicates that both females and males perceived their FL environments as equally conducive to L2 learning. This observation addresses reviewer's concern not to use gender data in a descriptive, but rather in a critical manner. Perhaps, the technology enabled and interactive elements of FL facilitated equitable participation opportunities which offset other classroom dynamics that may have disproportionately favored one gender over the other at their previous institution. Attitude data at both pre- and post-test demonstrated great improvement for students in the treatment group. These favorable changes further support the notion that FL can enhance learner autonomy, motivation and satisfaction where clear expectations and easily available digital material are provided. Students' higher degree of comprehension could be attributed to the fact they were able to replay video image explanations at a pace that suited them; such mechanical flexibility has long been cited in literature as an essential element for enabling students' mental and emotional readiness, before entering into a classroom based environment (Kurt, 2022; Lo & Hew, 2019). This component is responsive to the reviewers' suggestion that we empirically examine why attitudes change and not merely whether they do. A particularly interesting aspect of this study is the moderating effect computer literacy has on these attitudes. Findings indicated that students with poorer digital skills held more unfavorable attitudes toward FL despite benefiting academically. That matches with findings of previous studies showing that the readiness for technology is a

necessity to optimize learning outcome in blended and flipped approach (Kim et al., 2014; Zainuddin & Halili, 2016). The FL model assumes that students can access materials online, use digital content and printer well as = solve their way out of basic technical problems. Where such skill is not present, the learner may become frustrated or develop cognitive overload and thereby form negative attitudes to the procedure. This finding points to the importance for policymakers of adopting scalable FL study programs, however only after first closing large existing divides in digital training, particularly in countries with significant disparities in digital literacy. This enables this vein of insight to be tied more directly, as per reviewer suggestions, back into practice or policy considerations. Notwithstanding these promising findings, several caveats must be considered when interpreting these results. The study's limitations include being conducted in a single geographic location and a short 6-week intervention, which may limit the generalizability and long-term impact of the effects. Additionally, there is a possibility that students' self-reported attitudes could be biased due to social desirability concerns. Moving forward, research utilizing mixed-methods of collection observation in the classroom, interviewing participants and tracking data over time is needed to gather richer information about FL adoption among students. Furthermore, researchers may investigate differentiated FL models based on learners' digital readiness levels to avoid that technology becomes a barrier to equitable learning. Ultimately, this study contributes to the literature by offering empirical support for the proposal that FL can improve academic performance and student attitudes in chemistry with appropriate scaffolding, quality multimedia resources, and via consideration of learners' technological capability. These findings have significant implications for instructional reform in Jordan and other similar contexts, as they suggest that FL can promote 21st century learning skills provided it is backed up with sufficient digital infrastructure and training. While the study provides useful interpretation as to why flipped teaching may improve chemistry achievement and attitudes, caution in interpretation is warranted. The sampling was restricted to one public secondary school of Jordan hence it is also limitations to external validity for other populations and educational environments. Groups were taught by the same instructor to minimize variance due to different teaching interventions; however, there might still have been slight differences in teacher-student interactions that could influence students' learning experiences not captured fully. A further limitation is that the sex-specific analysis was performed among students in the EG. And although post-test performances were higher for females than males, it is impossible to determine how much of a difference in performance was the result of FL and how much could be attributed to other factors (e.g., prior

achievement, motivation, study behaviors) given that no gender comparisons exist for pre-test and CG. The design in this regard has not done justice to gender in future studies and should be more comprehensive in these aspects. A further limitation of this study concerns the nature of the achievement measure employed. The reliance on objective test items, while appropriate for generating consistent and quantifiable results, may not fully reflect the depth of students' chemical reasoning or the complexity of their conceptual understanding. Students' higher-order thinking processes and explanatory abilities might require more open-ended or performance-based forms of assessment. Future studies may therefore consider integrating qualitative or mixed assessment approaches to gain a richer picture of students' learning outcomes. Finally, reliance on multiple-choice testing for assessment of attainment may be limiting the extent to which assessment can account for students' level of understanding and their ability to use chemical thinking into more advanced problem-solving contexts. It would be interesting to investigate whether introducing open-response items or performance tasks into testing in the future could provide a more subtle and inclusive picture of what is considered learning to have been.

In practical terms, the findings of this study provide useful guidance for secondary chemistry teachers. Rather than relying mainly on lecture-based instruction, teachers may consider introducing short preparatory materials—such as concise video explanations before class, and then using classroom time for discussion, collaborative problem-solving, and application of chemical concepts. This shift allows students to engage more actively with the content and to develop a deeper understanding through guided interaction. The findings also highlight the importance of supporting students with different levels of digital proficiency, ensuring that all learners can participate effectively in the FL environment.

IMPLICATIONS AND RECOMMENDATIONS

Implications for flipped instruction These findings draw attention to the potential of the flipped model as a means of improving student engagement and performance in secondary chemistry classes in Jordan. Nevertheless, wider implementation of this teaching model is bound to consider the contingencies of national educational systems such as differences in school equipment, uneven availability of digital resources and variability in teachers' computer skills. Institutional support—especially involving the Ministry of Education—is therefore a pre-requisite for designing the necessary circumstances to facilitate sustainable implementation. One form such support might take is integrating principles of FL into the national curricula, revising

teaching standards and systemic investment in digital infrastructure in schools. In order to enhance the efficacy of the intervention, it is suggested that teachers be encouraged to use FL as a result of their ability to develop deeper understanding, engage students actively and decrease dependence on teacher-centered classes. Teachers also need targeted professional development that provides them with the skills to design and manage digital instructional materials, support students in learning independently and reflect on their needs according to their level of digital confidence (Aburayash, 2021). Moreover, future studies should examine FL in noneconomic subjects and at other educational levels to study if it is appropriate or not. More diverse school settings could be introduced to the research, which might add credibility to its findings. By enriching the empirical evidence, educational policy makers and practitioners can have a better understanding regarding how FL might be adapted to cater for diverse learners needs and result in sustainable education reform in Jordan.

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