

Effects of new teaching approaches on motivation and achievement in higher education applied chemistry courses: A case study in Tunisia

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ABSTRACT

New teaching approaches differ from classic ones in promoting active learning. Despite claims that new teaching approaches increase students' motivation and achievement, empirical research concerning these positive effects is scarce, specifically regarding effects on achievement. In the present investigation, we conducted a series of quasi-experimental studies to compare new with classic teaching approaches. In four studies, we investigated the impact of flipped courses - an innovating teaching method (vs. classic teaching) - and of three innovative test formats - journal format report (vs. classic report), research article analysis and exam with all documents authorised (vs. classic exam) - on the motivation and achievement of students taking applied chemistry courses at the Higher Institute of Applied Biology of Medenine, Tunisia. Students' motivation was increased by all new teaching approaches. Achievement scores were also significantly improved by these new methods, except for the exam with all documents authorized. Effect size calculations showed that all four new approaches had larger effects on motivation than on achievement, and that motivational vs. achievement benefits were unequally balanced across active learning tools.

Our findings strengthen the relevance of active learning tools in high-level applied chemistry teaching, but they highlight the need to consider priority goals (increased motivation vs. achievement) when adopting a particular learning tool.

1. Introduction

Educators are forever experimenting and innovating. A central theme in all this activity is the idea that *active learning* works best. Active learning is defined as any instructional method that *engages* students in the learning process and values their *autonomy*. Active learning is often contrasted to traditional lecturing, where students receive information from the instructor in a passive way (Prince, 2004). Multiple modalities of active learning have been explored, such as flipped courses, auto-tutorials, team learning, peer instruction, inquiry learning, just-in-time teaching, blended classrooms, hybrid courses, or process-oriented guided inquiry learning (Herreid and Schiller, 2013; Liyanage et al., 2021). Active learning includes not only alternatives to traditional ways of structuring classes (passive lecture attendance), but also alternatives to traditional exams: these consist of new test formats such as journal format reports, article analysis reports or exams with all documents authorized, which may also enhance students' autonomy

and engagement in the learning process. As pointed out by Crooks (1988), classroom evaluation affects students in many ways: It guides their judgment of what is important to learn, structures their approaches to and timing of personal study (e.g., spaced practice), consolidates learning, and affects the development of enduring learning strategies and skills. Therefore, test formats are as important as teaching methods in a strict sense when it comes to shape the learning process.

Why should active learning work best, compared to traditional methods? One the one hand, it is known that traditional (passive) lecturing in higher education is largely ineffective with respect to comprehension and retention (Halloun and Hestenes, 1985; Roberts, 2019; Seymour and Hewitt, 1997). One the other hand, a well-established idea, shared by the Self-Determination Theory applied to educational contexts (Ryan and Deci, 2020), is that students' engagement and autonomy – the core elements of active learning - increase their intrinsic motivation (Yoon et al., 2020). Intrinsic motivation relates to inherent interest and enjoyment, as opposed to extrinsic

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motivation - a minor form of motivation that is regulated by external rewards and punishments. Besides intrinsic motivation, engagement and autonomy would also enhance students' academic achievement (Ryan and Deci, 2020). In line with this, Coppola and Pontrello (2020) claimed that active learning makes students take more ownership of their learning (autonomy) and, thus, to develop a deeper understanding of contents (achievement). From this viewpoint, increased motivation and increased achievement could both result from replacing traditional (passive) methods with active ones.

Although new teaching approaches incorporating active learning principles seem promising, empirical findings regarding their actual impact on students' motivation and achievement are not abundant. Specifically, we know little on whether motivation and achievement benefit in equivalent ways from these new approaches. Determining this is fundamental, in that motivation without achievement is useless from a pragmatic viewpoint, and achievement without motivation represents a lesser form of personal growth (Ryan and Deci, 2020) that potentiates academic drop-out.

For instance, among new teaching methods (new ways of structuring classes), *flipped courses* have received great attention. Flipped courses consist of presenting materials to students in advance, thus enabling active learning environments to take place during formal class time - such as case studies, labs, games, simulations, or experiments (Fulton, 2012). In contrast to traditional methods, students take lessons at home and do homework in class. The flipped course approach was originally conceived to allow all learners to engage with lecture material (Lage et al., 2000). It has been suggested that flipped courses have the potential to improve both motivation and achievement (Fulton, 2012; Hernández-correa et al., 2019; Kusumoto, 2018; Mora et al., 2020; Partanen, 2020), but empirical findings are not clear-cut in this matter: In a review that covered twelve publications on flipped courses in higher education chemistry teaching, Seery (2015) found that students' preference for flipped courses over traditional ones was consensual across studies, but the results on achievement levels were evenly divided.

Regarding new test formats, these are alternative assessment practices to classical examination, which is generally based on memory questions and dissertations. In the context of active learning, new test formats strongly relate to the concept of *authentic assessment*. Authentic assessment replicates real-world challenges and standards of performance that experts or professionals typically face in the field. It requires students to demonstrate their deep understanding, higher-order thinking, and complex problem solving through the performance of exemplary tasks (Koh, 2017). New test formats tend to head towards authentic assessment, in the sense that they typically engage a strong performance component, as well as a focus on real world contexts (bin Mubayrik, 2020). Empirical findings suggest that performance-based evaluation may enhance both motivation and achievement (Clarkson et al., 2000; Hancock, 2007) compared to traditional evaluation methods, but direct comparisons remain scarce.

Although active learning approaches may benefit any area of education, the areas that combine complex and abstract declarative knowledge with real-world problem-solving are perhaps those that benefit the most from these tools: Real-world problem-solving requires autonomy and commitment, and it is not compatible with passive exposure to abstract contents, especially when these are highly complex. High-level applied chemistry, including chemical engineering, is one such area. Throughout her experience as an applied chemistry Professor in a Higher institute marked by traditional teaching practices (Higher Institute of Applied Biology of Medenine, Tunisia), the first author has been struggling with students' lack of motivation and academic achievement. At the end of the 2017–2018 academic year, we performed a survey on a random sample of 50 applied chemistry students attending the Higher Institute. They were asked if new pedagogical approaches during courses or exams might be motivating for them. We found then that all students unanimously approved this proposal.

In the present investigation, we compared the effects of several

active learning tools on applied chemistry Tunisian students' motivation vs. achievement: Do motivation and achievement benefit from new teaching approaches? If so, is there a similar enhancing effect on these two dimensions? To achieve our goal, we ran four quasi-experimental studies, one on teaching methods (Study 1) and the other three on new test formats (Studies 2–4, Table 1). The groups in each study corresponded to groups of students attending one course.

Study 1 was conducted to compare a flipped course to a traditional one in terms of motivation and acquired knowledge. Study 2 focused on a comparison between a journal format report and a classical report. Studies 3 and 4 compared classical exams with exams based on the analysis of a research article analysis (study 3), and with exams with all documents authorised (study 4). Studies were run on student participants who had the same Professor, and whose backgrounds regarding learning experiences were based on traditional teaching and evaluation. All four active learning tools were designed to increase engaging and autonomy. New test formats had the additional potential to fight students' cheating, since these did not require the reproduction of the course, but only analysis, reflection and critical thinking.

1.1. Study 1: flipped vs. classical course

This study used a within-subjects design. During a green chemistry course, a single group of students was taught with flipped vs. classical methods. Motivation and achievement levels were compared across conditions. The flipped course was expected to increase the engagement of students and develop their critical-thinking skills.

2. Methods

2.1. Participants

Twenty students ($M \pm SD = 23.43 \pm 0.89$ years) at master level first year (Baccalaureate + 4 years) took part in this experiment. All students were women (95 % of students in the institution were female).

2.2. Procedure

Students started with the flipped course and then underwent the classic course. The classic course consisted in a lecture where the scientific content of the lesson was entirely presented by the teacher and students were not allowed to participate in any discussion. In the inverted (flipped) course, students got access to the scientific contents through a paper-based document a week before the planned date for the course. During study time, discussion-reflection activities with the teacher and peers were allowed.

At the end of each course a test was performed. Each end-course test contained two questions: the first asked students about their level of motivation during the course on a scale from 0 to 5, and the second one was a scientific question to check if they had assimilated the new information that was taught. Knowledge questions had the same level of difficulty across courses (Appendix A).

2.3. Statistical analysis

For each student, we computed the average motivation scores (0–5) and the average knowledge scores (0–1) for classic vs. inverted courses across the three tests. We then compared motivation and knowledge scores across course types (flipped vs. classic) using one-tailed paired-samples t-tests. Due to violations of normality assumptions, we ran non-parametric (Wilcoxon signed ranks) tests for cross-check. Significance levels of 0.05 were adopted.

3. Results

Motivation scores were significantly higher for flipped courses ($M \pm$

Table 1
Summary of studies.

	Study 1: Flipped course vs. Passive lecture	New test formats		
		Study 2: Journal format report vs. Classic report	Study 3: Research article analysis vs. classic exam	Study 4: All-documents-authorised vs. classic exam
Topic of the course	Green Chemistry	Cosmetic formulation	Water treatment	Cosmetics and regulations
Group	master level first year (Baccalaureate + 4 years)	master level second year (Baccalaureate + 5 years)	master level first year (Baccalaureate + 4 years)	master level second year (Baccalaureate + 5 years)
Sample	20	30	30	60
Design	Within-subjects	Between-subjects	Between-subjects	Between-subjects
Measures	Self-reported motivation and objective achievement			

$SD = 3.51 \pm 0.77$) compared to classic ones (2.70 ± 0.84 ; $t(19) = 13.27$, $p < .001$, $d = 2.96$). The same went for knowledge scores (flipped: 0.93 ± 0.13 ; classic: 0.73 ± 0.44 ; $t(19) = 2.69$, $p = .007$, $d = 0.60$). Wilcoxon signed-ranks tests did not change the pattern of results, showing significantly increased motivation ($Z = 0.00$, $p < .001$) and knowledge ($Z = 0.00$, $p = .016$) for flipped courses.

4. Discussion

Results showed that a flipped course may be a source of motivation compared to classic courses, and that it may also induce greater knowledge acquisition within students.

4.1. Study 2: journal report vs. classical report test-formats

We compared the effects of two report-based test formats - journal format vs. classical report - on motivation and achievement. The study was carried out during a practical course of cosmetic formulation, using a between-subjects design. The journal format report was expected to increase motivation due to its innovative characteristics.

5. Methods

5.1. Participants

Thirty students at master level second year (Baccalaureate + 5 years) participated in the experiment. Students were divided in two similar groups, matched for age and performance as demonstrated by chemistry exam marks during the previous semester (group 1: Mean age $\pm SD = 24.60 \pm 0.50$ years; Mean exam marks $\pm SD = 13.47 \pm 0.52$ points out of 20; group 2: Mean age $\pm SD = 24.2 \pm 0.41$ years; Mean exam marks $\pm SD = 13.33 \pm 0.62$). All students were women.

5.2. Procedure

Half the students ($n = 15$) were asked to present the results of the practical course using a classical report document (Appendix B, exam format 1), while the other half was asked to do it using a journal format (exam format 2). The classical report format consisted of a set of standard questions - typical of all practical exams regardless of the subject - to which students should provide concise answers. In contrast, the journal report format had the structure of a press paper. The student played the role of a journalist, filling in the different parts of the report with text dissertation, and pasting photos to complement.

All students had the same end-practical course test, containing two questions: the first asking students about their level of motivation regarding the way of reporting their results, and the second question was a scientific question (same for both groups) to see if they had acquired the information taught (Appendix B).

5.3. Statistical analysis

For each student, we computed the average motivation scores (0–5) and the average knowledge scores (0–1) for classic vs. inverted courses across the three tests. We then compared motivation and knowledge scores across report formats (journal-based vs. classic) with one-tailed independent-samples t-tests. Again, due to violations in assumptions of normality and/or equality of variances, we used the alternative non-parametric tests (Mann-Whitney) for cross-check. Significance levels of 0.05 were adopted.

6. Results

The journal-format group showed increased levels of motivation ($M \pm SD = 4.73 \pm 0.45$; $t(28) = -4.72$, $p < .001$, $d = 1.72$) and knowledge ($M \pm SD = .93 \pm .25$; $t(28) = -2.68$, $p = .006$, $d = 0.98$) compared to the classic group (motivation: $M \pm SD = 2.80 \pm 1.52$; knowledge: $M \pm SD = .53 \pm .51$). Non-parametric tests showed equivalent results (Motivation: Mann-Whitney $U = 27.0$, $p < .001$; Knowledge: Mann-Whitney $U = 67.5$, $p = .008$).

7. Discussion

This experiment showed that the journal format report exam increased students' motivation compared to the classic report exam, and that it also triggered better understanding and knowledge acquisition.

7.1. Study 3: research article analysis vs. classical exam formats

We ran this study during a water treatment course. As in study 2, we analysed the effects of two different test formats on motivation and achievement across two groups of students. The test formats corresponded to exam types, one classical and the other based on the analysis of a research article. The latter format was designed to enhance synthesis and critical thinking in students.

8. Methods

8.1. Participants

Thirty students at master level first year (Baccalaureate + 4 years) participated in the experiment. The group of students was divided in two similar groups, with similar age and performance level (group 1: Mean age $\pm SD = 23.46 \pm 1.1$ years; Mean exam marks $\pm SD = 15.00 \pm 0.86$; group 2: Mean age $\pm SD = 23.06 \pm 0.77$ years; Mean exam marks $\pm SD = 15.31 \pm 0.79$). All students were women.

8.2. Procedure

Half the students ($n = 15$) had a final semester exam based on the analysis of a research article (Appendix C, Exam Format: Research article analysis exam). The other half had a classical exam based on

classical questions and calculation exercises, as also displayed in [Appendix C](#).

In addition, students in both groups were asked about their level of motivation when studying for the exam. As in study 2, achievement scores were extracted from exams themselves. Exam grades ranged from 0 to 20. However, for comparison with previous studies, we converted grades to 0 (<10) vs. 1 (10 or >10) scores.

8.3. Statistical analysis

The analysis was the same as in study 2.

9. Results

The research article analysis group showed increased levels of motivation ($M \pm SD = 4.46 \pm 0.91$; $t(28) = 6.78$, $p < .001$, $d = 2.47$) and knowledge ($M \pm SD = .86 \pm 0.85$; $t(28) = 2.06$, $p = .024$, $d = 0.75$) compared to the classic group (motivation: $M \pm SD = 2.00 \pm 1.06$; Knowledge: $M \pm SD = .53 \pm .51$). Non-parametric tests did not change the results (Motivation: Mann–Whitney $U = 212.5$, $p < .001$; Knowledge: Mann–Whitney $U = 150.0$, $p = .027$).

10. Discussion

Once again, results showed increased motivation and knowledge acquisition in students undergoing a new test format, in this case a research article analysis format.

10.1. Study 4: all documents authorized vs. classical exam

The third new exam format we tested was an exam with all documents authorized. We tested it against a classical exam during a cosmetics and regulations course. The all-documents-authorized format was designed to develop synthesis and critical thinking in students, by fostering learning without relying on memorisation. As in study 3, students were also discouraged from cheating ([Harper et al., 2021](#)).

11. Methods

11.1. Participants

Sixty students at master level second year (Baccalaureate + 5 years) participated in the experiment. The group was divided in two similar groups, with same age and competences (chemistry exam mark) during the previous semester (group 1: Mean age $\pm SD = 23.45 \pm 1.09$ years; Mean exam marks $\pm SD = 13.83 \pm 0.73$; group 2: group 1: Mean age $\pm SD = 23.47 \pm 1.10$ years; Mean exam marks $\pm SD = 13.86 \pm 0.86$). All students were women.

11.2. Procedure

Half the students ($n = 30$) had a final semester exam with all documents authorized, meaning that they could consult any materials they wished to. The exam was composed by questions on a cosmetic product as displayed in [Appendix D](#) (all documents authorised exam). The other half had a classical exam based on an open question.

Students in both groups were asked about their level of motivation when studying for the exam. As in study 3, Achievement scores were extracted from exams themselves. Exam grades ranged from 0 to 20, but they were converted to 0 vs. 1.

11.3. Statistical analysis

The analysis was the same as in studies 2 and 3.

12. Results

The all-documents-authorized group showed increased levels of motivation ($M \pm SD = 4.06 \pm 1.22$; $t(58) = 2.33$, $p = 0.011$, $d = 0.60$) compared to the classic group ($M \pm SD = 3.26 \pm 1.41$), but knowledge levels did not differ significantly across groups ($p = .070$, $d = 0.39$). Non-parametric tests showed the same pattern. (Motivation: Mann–Whitney $U = 606.5$, $p = .009$; Knowledge: Mann–Whitney $U = 525.0$, $p = .071$).

13. Discussion

This experiment showed that the exam with all documents authorized is a source of increased motivation compared to the classic exam. The fact that there was no effect on exam scores suggests that the access to wide resources does not constitute an advantage towards classical exams, where the access to resources other than memory is absent.

13.1. Comparison of effect sizes across studies

[Fig. 1](#) displays effect sizes for the comparisons addressed in studies 1–4. Concerning motivation, all effect sizes were large ($d > 0.80$) except for all documents authorized vs. classical exam (medium, $d > .50$). The largest effect size was found for the comparison between flipped vs. classical courses, followed by journal vs. classical reports, then by research article analysis vs. classical exams, and finally by all documents authorized vs. classical exam formats.

For achievement, we found a large effect size in the comparison journal vs. classical report (largest effect). Medium effect sizes ($d > 0.50$) were found for the comparisons article analysis vs. classical exam and flipped vs. classical course. The comparison all-documents-authorized vs. classical exam showed a small effect size ($d = 0.39$).

13.2. General discussion

Throughout her teaching experience in Tunisia, the first author noted that high-level applied chemistry students used to dislike classical exams based on memory questions and dissertations, and that they complained about traditional lectures. Together with the presence of open questions in the literature regarding the actual benefits of active over passive learning, such circumstances motivated the present series of studies, comparing innovative with classic teaching methods and exam formats. Four studies were run: Study 1 was conducted to compare a flipped course to a traditional one. Study 2 focused on a comparison between a journal format report and a classical report. Studies 3 and 4 compared classical exams with exams based on the analysis of a research article analysis (study 3) and with exams with all documents authorised (study 4). All studies analysed effects on both motivation and achievement, so that we could determine (1) whether both motivation and achievement benefitted from active learning tools, and (2) whether the

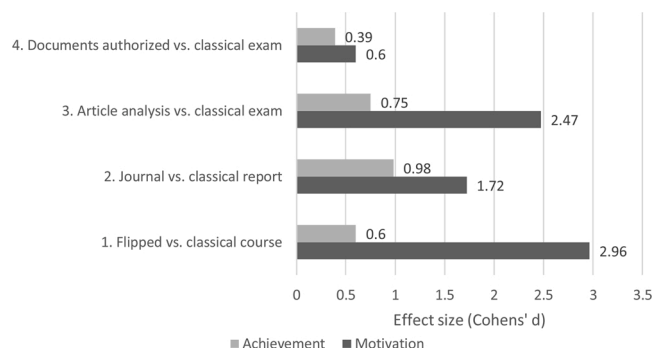


Fig. 1. Effect sizes for comparisons addressed in studies 1 to 4.

benefits were equivalent across the two dimensions.

Regarding (1) the impact of active learning tools on motivation and achievement, results showed significant enhancing effects from all tools, except one (impact of all documents authorized exam on achievement). For new learning methods such as *flipped courses* (study 1), results showed that these may be not only more motivating compared to classic ones, but also that they may foster knowledge acquisition. These results are in accordance with those of [Weaver and Sturtevant \(2015\)](#), who, after three years using ACS (American Chemical Society) standardized exams, implemented flipped courses and saw that scores in the latter were significantly higher by almost one standard deviation when compared with students' previous scores in the traditional courses. Our findings are also in line with a recent meta-analysis on the effects of flipped courses on learning outcomes ([van Alten et al., 2019](#)). In this meta-analysis, the author demonstrated a clear positive impact of flipped courses and stressed the specific potential of face-to-face time and quiz activities, which seem to show the largest effect size. Concerning the effects of new test formats – specifically of innovative report formats (study 2) – we found that the *journal format report* thrived student's motivation and achievement compared to a classical report format. Preparing a journal was a challenging task to our students, as the format of the classical report they were used to was known in advance (the same question format for all practical courses had been used during graduation). Unlike classical reports, the journal report format entails performance assessment, in that students are asked to demonstrate their achievement by engaging in individual or group activities, producing an extended written or spoken answer, or creating a specific product ([Nitko, 1996](#)). Our results agree with those of [Hancock \(2007\)](#) where students demonstrated increased knowledge and skills and were significantly more motivated to continue learning during a performance assessment format than in classic exams. As for innovative exam formats, both the *research article analysis* (study 3) and the *exam with all documents authorized* (study 4) increased students' motivation, but only the research article analysis improved achievement. The fact that the exam with all documents authorized failed to boost students' achievement contrasts with results from other studies. For instance, [Moore, 2018](#) reported that students improved their ability to organize their knowledge when access to specific journal resources and articles was permitted. One possible explanation for the failure of the all-documents-authorized format in our study may relate to the fact that this was a novel circumstance for our students, and that did not have the time and/or training required to autonomously make use of available resources during the exam. Further investigation on all-documents-authorized exams should lead to better understanding of the parameters affecting knowledge acquisition.

Concerning (2) the benefits of active learning tools for motivation vs. achievement, effect sizes for all comparisons pointed to an increased positive impact on motivation. A simple explanation that cannot be ruled out may be related to the different scales we used to measure motivation (0–5) and achievement (0–1), which may have induced different discrimination levels across the two dimensions. If this was not the case, one should consider the possibility that active learning tools are indeed highly motivating, but they do not necessarily elicit comparable boosts in achievement. Thus, although the feelings of arousal, alertness, attention and concentration that relate to increased motivation may trigger productivity and achievement ([Ainley, 2006](#)), this may not necessarily be so in every circumstance. From this viewpoint, the claims made by self-determination theory – that motivation and achievement follow engagement and autonomy ([Ryan and Deci, 2020](#)) –

may require further test.

Related to (2), we saw that the balance between motivation benefits and achievement benefits regarding active learning effects varied considerably across active learning tools. Specifically, the journal format report (vs. classic report) showed the most balanced outcomes in terms of motivation vs. achievement (motivational benefits approximately doubled achievement ones). It was followed by the article analysis exam (vs. classic exam, motivational benefits three times higher), and then by the flipped course (vs. traditional course), where motivational benefits were almost five times higher than achievement benefits. As for the all-documents-authorized (vs. classic exam) comparison, motivational vs. achievement benefits were quite balanced, but they were both low. In face of that, we focus the discussion on the first three comparisons: So, why would the journal format report provide the best balance between motivation and achievement, meaning that achievement was maximized? One possibility is that presenting information in a journal format – in plain, readable language directed to a large audience – requires a deep understanding of the contents (perhaps the deepest form of understanding one could imagine), and this affects achievement. In comparison, analyzing a research article may not have the same impact on achievement because students remain within the boundaries of scientific language, do not need to perform the crucial translation between academic and non-academic communication, and thus their understanding of scientific contents is not pushed so far. As for the comparison between flipped and traditional courses, one reason why achievement may have lagged largely behind motivation may be that evaluation was made with traditional tools, thus not allowing the expression of acquired knowledge in a proper manner ([Tokan and Imakulata, 2019](#)). These possibilities remain as open questions for future research.

Along with future research directions that have already been pointed (reasons for the lack of efficacy of all-documents-authorized exams, reasons for greater impact of active learning on motivation vs. achievement, different balances between motivational and achievement benefits following different active learning tools), future studies could also address some of our methodological options in a critical manner, since they may have induced limitations in our study. One of these concerns the quasi-experimental status of our approach, which was not based on a random distribution of subjects across groups. Another limitation may lie in the measure of motivation we used – simple ratings of self-perceived motivation on a scale from 0 to 5. Third, the fact that we ran our studies on applied chemistry students attending an applied biology course – thus not necessarily motivated to study chemistry, as would be the case of chemical engineers – may have magnified the impact of active learning tools on motivation. Finally, the fact that studies were run with students with little experience with active learning methods, may have had a similar boosting effect.

Despite the limitations of our pilot study, our findings support the ideas that new teaching and examination strategies may foster a growth mindset ([Lin-Siegler et al., 2016](#)) and that, if we succeed in changing students' mindsets, we could boost student's achievement ([Sisk et al., 2018](#)). The nuances we saw for the effects of different new strategies raise new questions, allowing future refinements of the concept of active learning.

14. Conclusion

Besides strengthening the idea that active learning has benefits in high-level applied chemistry teaching, the series of quasi-experiments conducted in the present pilot study highlighted two new ideas that

may feed future research: First, the effects of active learning tools seem to be larger for motivation than for achievement. Second, among new test formats, there seem to be differences regarding the magnitude of the impact each one has on motivation vs. achievement. Therefore, choosing to invest on new teaching methods vs. new test formats, or choosing among one particular new test format seems to have non-negligible consequences. Further research on this area may help overcome the limitations of traditional teaching in applied chemistry, so that students become better prepared to face the challenges of today's world.

Declaration of Competing Interest

- ✓ All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version.

- ✓ This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.
- ✓ The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript
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Appendix A. Flipped course

Test 1: Inverted course

Name.....Family name.....

1/ Check the level of motivation in the attached grid:

2/ Check the right answer:

Green chemistry is:

☐ the chemistry of green elements in nature and environment

☐ named also ecological chemistry or sustainable chemistry

Test 2: Classic course

Name.....Family name.....

1/ Check the level of motivation in the attached grid:

2/ Answer with Yes or No:

Organic chemistry synthesis economizes atoms. **Yes / No**

Organic chemistry synthesis is pollutant. **Yes /No**

Organic chemistry synthesis economizes energy. **Yes /No**

Test 1: Inverted course

Name.....Family name.....

1/ Check the level of motivation in the attached grid:

2/ Check the right answer:

Green chemistry is:

☐ the chemistry of green elements in nature and environment

☐ named also ecological chemistry or sustainable chemistry

Test 3 : Inverted course

Name.....Family name.....

1/ Check the level of motivation in the attached grid:

2/ Answer with Yes or No:

The atomic use of a reaction is its yield **Yes /No***The more E factor is near zero the more synthesis process generates waste **Yes/ No****Test 4 : Classic course**

Name.....Family name.....

1/ Check the level of motivation in the attached grid:

2/ which synthesis process of ibuprofene respects green chemistry principles

A) BHC

B) Boots

Test 5 : Inverted course

Name.....Family name.....

1/ Check the level of motivation in the attached grid:

2/ Link with an arrow related words:

DDT Persistent Organic Pollutants

Ibuprofene chilling gaz

POP insecticide

Urethane anti-inflammatory

CFC poison

Phosgene monomer (plastic)

Test 6 : Classic course

Name.....Family name.....

1/ Check the level of motivation in the attached grid:

2/ Check green solvents :

Alcohol

water

Acetone

CO₂

Pyridine

Appendix B. Exam Format: Classical report on A4 paper size**Practical preparation of Natural-cosmetics**

Aim:

Principle:

Materials and methods

How are Natural Cosmetics are made?

Selection of prepared products:

The particular product to be commercialized:

Exam Format: New report on A3 paper size

Results

(continued on next page)

(continued)

..... Conclusion

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Appendix C. Exam Format: Research article analysis exam

Read the furnished article named: Demineralization of/ brackish water for drinking water supply cities of Gabes and Zarzis, witten by K. Walha et al. and published at J. Soc. Chim. Tunisie, 2007, 9, 133–142 135.

Answer the following 12 questions, and choose the right one when choices are displayed.

Question	Answer	Question	Answer
What is the nature of treated water?	Dam water/Sea water /River water / Artesian aquifer/ Other	What is the most mobile cation across the membrane and why?	
Once treated, will the water be drinkable?	Yes/NO	Mobility is	concentration / speed/ distance
Knowing that conductivity is directly proportional to salinity, which of the two waters is the most saline? That of Gabes or Zarzis?		Define the retention rate of ions by a membrane	
Water is most treated in which field?		Set the conversion rate	
Why did the researchers proceed by ED for the		Why does RO-treated water not require additional	

(continued on next page)

(continued)

Question	Answer	Question	Answer
desalination of the waters of Gabes and by RO for the water of Zarzis?		remineralisation treatment?	
Why?			
Complete the following sentence	Electrodialysis consists of removing dissolved salts in water by migration through ion exchange membranes under the action of an electric field. While reverse osmosis is.....		

Classic Exam Format

- Question 1:
Why treating water is a necessity and what are the types of water that can be treated?
- Question 2:
Filling the following table:

Water	Salinity	EC(mS/cm)
Sea water		
Brackish water		
Spring water		

- Question 3:
Elaborate a comparison between Electro-dialysis and reverse osmosis.

Appendix D. Exam Format: all documents authorised exam.

Considering the following cosmetic product label complete the table to determine its characteristics:



Question : fill in and/or give explanation	Answer	Question	Answer
Ingredients according INCI Yes/NO		Presence of yogurt	
Full labelling ingredients Yes/NO		Natural ingredients	
Number of ingredients		Tested on animals or potential users: Yes/No	
Major constituent / Minor constituent		Explain	
Excipient		Promotes fair trade: Yes /No	
Preservative		Explain	
Emulsifier		Made in	
Perfume		Volume	
Presence of mineral oils Yes/NO		Indications	
Presence of ingredients from plants Yes /NO		Restrictions	
Presence of ingredients from animals Yes/NO			

Classic Exam Format

Subject: What can be the indications on the packaging of a cosmetic? Give examples.

References

- Ainley, M., 2006. Connecting with learning: motivation, affect and cognition in interest processes. *Educ. Psychol. Rev.* 18 (4) <https://doi.org/10.1007/s10648-006-9033-0>.
- bin Mubayrik, H.F., 2020. New trends in formative-summative evaluations for adult education. *Sage Open* 10 (3). <https://doi.org/10.1177/2158244020941006>.
- Clarkson, S., Mills, P., Sweeney, Wv., Marino, R., 2000. A new approach to teaching introductory science: the gas module. *J. Chem. Educ.* 77 (9) <https://doi.org/10.1021/ed077p1161>.
- Coppola, B.P., Pontrello, J.K., 2020. Student-generated instructional materials. *Active Learning in College Science*. Springer International Publishing, pp. 385–407. https://doi.org/10.1007/978-3-030-33600-4_24.
- Crooks, T.J., 1988. The impact of classroom evaluation practices on students. *Rev. Educ. Res.* 58 (4) <https://doi.org/10.3102/00346543058004438>.
- Fulton, K., 2012. Upside down and inside out: flip your classroom to improve student learning. *Learn. Lead. Technol.* 39, 12–17.
- Halloun, I.A., Hestenes, D., 1985. Common sense concepts about motion. *Am. J. Phys.* 53 (11) <https://doi.org/10.1119/1.14031>.
- Hancock, D.R., 2007. Effects of performance assessment on the achievement and motivation of graduate students. *Act. Learn. High. Educ.* 8 (3) <https://doi.org/10.1177/1469787407081888>.
- Harper, R., Bretag, T., Rundle, K., 2021. Detecting contract cheating: examining the role of assessment type. *High. Educ. Res. Dev.* 40 (2) <https://doi.org/10.1080/07294360.2020.1724899>.
- Hernández-Correa, J., Pertuze, J., Hilliger, I., Pérez-Sanagustín, M., 2019. Students' Adoption and Learning Outcomes in a MOOC-based Flipped Course. *EC-TEL*.
- Herreid, C.F., Schiller, N.A., 2013. Case study: case studies and the flipped classroom. *J. Coll. Sci. Teach.* 42 (5), 62–66.
- Koh, K.H., 2017. Authentic assessment. *Oxford Research Encyclopedia of Education*. Oxford University Press. <https://doi.org/10.1093/acrefore/9780190264093.013.22>.
- Kusumoto, Y., 2018. Enhancing critical thinking through active learning. *Lang. Learn. High. Educ.* 8 (1) <https://doi.org/10.1515/cercles-2018-0003>.
- Lage, M.J., Platt, G.J., Treglia, M., 2000. Inverting the classroom: a gateway to creating an inclusive learning environment. *J. Econ. Educ.* 31 (1), 30–43. <https://doi.org/10.2307/1183338>.
- Lin-Siegler, X., Dweck, C.S., Cohen, G.L., 2016. Instructional interventions that motivate classroom learning. *J. Educ. Psychol.* 108 (3) <https://doi.org/10.1037/edu0000124>.
- Liyanage, D., Lo, S.M., Hunnicutt, S.S., 2021. Student discourse networks and instructor facilitation in process oriented guided inquiry physical chemistry classes. *Chem. Educ. Res. Pract.* 22 (1) <https://doi.org/10.1039/D0RP00031K>.
- Moore, C.P., 2018. Adding authenticity to controlled conditions assessment: introduction of an online, open book, essay based exam. *Int. J. Educ. Technol. High. Educ.* 15 (1) <https://doi.org/10.1186/s41239-018-0108-z>.
- Mora, H., Signes-Pont, M.T., Fuster-Guilló, A., Pertegal-Felices, M.L., 2020. A collaborative working model for enhancing the learning process of science & engineering students. *Comput. Human Behav.* 103. <https://doi.org/10.1016/j.chb.2019.09.008>.
- Nitko, A.J., 1996. *Educational Assessment of Students*, second edition. Prentice-Hall Order Processing Center, P.O. Box 11071, Des Moines, IA, pp. 50336–51071. (\$77).
- Partanen, L., 2020. How student-centred teaching in quantum chemistry affects students' experiences of learning and motivation—a self-determination theory perspective. *Chem. Educ. Res. Pract.* 21 (1) <https://doi.org/10.1039/C9RP00036D>.
- Prince, M., 2004. Does active learning work? A review of the research. *J. Eng. Educ.* 93 (3) <https://doi.org/10.1002/j.2168-9830.2004.tb00809.x>.
- Roberts, D., 2019. Higher education lectures: from passive to active learning via imagery? *Act. Learn. High. Educ.* 20 (1) <https://doi.org/10.1177/1469787417731198>.
- Ryan, R.M., Deci, E.L., 2020. Intrinsic and extrinsic motivation from a self-determination theory perspective: definitions, theory, practices, and future directions. *Contemp. Educ. Psychol.* 61 <https://doi.org/10.1016/j.cedpsych.2020.101860>.
- Seery, M.K., 2015. Flipped learning in higher education chemistry: emerging trends and potential directions. *Chem. Educ. Res. Pract.* 16 (4) <https://doi.org/10.1039/C5RP00136F>.
- Seymour, E., Hewitt, N.M., 1997. *Talking About Leaving: Why Undergraduates Leave the Sciences*. Westview Press.
- Sisk, V.F., Burgoyne, A.P., Sun, J., Butler, J.L., Macnamara, B.N., 2018. To what extent and under which circumstances are growth mind-sets important to academic achievement? Two meta-analyses. *Psychol. Sci.* 29 (4) <https://doi.org/10.1177/0956797617739704>.
- Tokan, M.K., Imakulata, M.M., 2019. The effect of motivation and learning behaviour on student achievement. *South Afr. J. Educ.* 39 (1) <https://doi.org/10.15700/saje.v39n1a1510>.
- van Alten, D.C.D., Phielix, C., Janssen, J., Kester, L., 2019. Effects of flipping the classroom on learning outcomes and satisfaction: a meta-analysis. *Educ. Res. Rev.* 28. <https://doi.org/10.1016/j.edurev.2019.05.003>.
- Weaver, G.C., Sturtevant, H.G., 2015. Design, implementation, and evaluation of a flipped format general chemistry course. *J. Chem. Educ.* 92 (9) <https://doi.org/10.1021/acs.jchemed.5b00316>.
- Yoon, S., Kim, S., Kang, M., 2020. Predictive power of grit, professor support for autonomy and learning engagement on perceived achievement within the context of a flipped classroom. *Act. Learn. High. Educ.* 21 (3) <https://doi.org/10.1177/1469787418762463>.