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# The impact of flipped classroom approach on students' metacognitive awareness: a correlational analysis

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***Abstract.*** *Introduction.* The study of metacognitive processes in education, particularly the active implementation of flipped classroom approach, has recently garnered significant attention from researchers. *Aim.* The present research *aims* to investigate the relationship between the contribution of flipped classroom approach to the development of the educational process and its impact on students' metacognitive awareness. *Methodology and research methods.* The study extensively utilised qualitative, non-experimental, and correlational methods to analyse the impact of flipped classroom approach on students' metacognitive skills. The Metacognitive Awareness Inventory (MAI) questionnaire served as the primary assessment tool. The students' level of education and their academic performance were considered as variables. The sample comprised 212 students from three high schools in the Casablanca-Settat academic region. Data obtained from the MAI questionnaire were pre-analysed using IBM SPSS version 23 software. *Results.* The results of the study confirm a significant correlation between the implementation of flipped classroom approach and the enhancement of student metacognitive awareness, particularly in areas related to self-regulation and problem-solving strategies. Throughout the study, it was observed that the use of flipped classroom approach can substantially improve students' ability to manage their own learning processes. This underscores the importance of integrating metacognitive strategies into teaching methods to achieve the desired educational outcomes. *Scientific novelty.* This study contributes to the discussion on how flipped classroom approach influences metacognitive processes, providing students with opportunities to adopt more effective learning strategies. *Practical significance.* The present study offers valuable insights for educators, researchers, and decision-makers seeking innovative strategies to enhance educational outcomes for students.

***Keywords:*** flipped classroom, metacognitive awareness, Metacognitive Awareness Inventory (MAI), students, learning process

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# Влияние технологии «перевернутый класс» на метакогнитивную осведомленность студентов: корреляционный анализ

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***Аннотация.*** *Введение.* Исследование метакогнитивных процессов в образовании в целом и активное использование технологии «перевернутый класс» в образовательном процессе в частности в последнее время привлекают все большее внимание исследователей. *Цель* – исследование взаимосвязи между вкладом технологии «перевернутый класс» в развитие образовательного процесса и ее влиянием на состояние метакогнитивной осведомленности студентов. *Методология и методы исследования.* В исследовании широко использовались количественные, неэкспериментальные и корреляционные методы для анализа влияния технологии «перевернутый класс» на состояние метакогнитивных навыков студентов, в том числе опросник Metacognitive Awareness Inventory (MAI) в качестве основного инструмента оценки. В качестве переменных были приняты уровень школьного образования учащихся и их академические результаты. Выборка состояла из 212 учеников 3 старших школ академического региона Сеттат г. Касабланка. Данные, полученные с помощью опросника MAI, были проанализированы с помощью программного обеспечения IBM SPSS 23. *Результаты исследования* подтверждают значительную корреляцию между результатами использования технологии «перевернутый класс» и достижением более высоких уровней метакогнитивной осведомленности учащихся, особенно в областях, связанных с саморегуляцией и методами решения проблем. В ходе исследования было установлено, что применение технологии «перевернутый класс» может существенно повысить способность студентов управлять процессами собственного обучения, что подчеркивает важность влияния интеграции метакогнитивных стратегий на развитие методов преподавания для достижения заявленных образовательных результатов. *Научная новизна.* Данное исследование вносит определенный вклад в дискуссию о путях влияния технологии «перевернутый класс» на процессы метапознания с целью предоставления студентам возможностей применения лучших подходов к обучению. *Практическая значимость.* Настоящее исследование дает отличные результаты для школьных педагогов, исследователей и лиц, принимающих решения, в поиске новых путей для повышения образовательных результатов учащихся.

***Ключевые слова:*** перевернутый класс, метакогнитивная осведомленность, Metacognitive Awareness Inventory (оценка метакогнитивной осведомленности), студенты, процесс обучения

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## Introduction

In the current educational context, innovative teaching methods are overtaking traditional approaches, making learning more active, autonomous and learner centred, according to OCDE [1]. F. Zhang, H. Wang, H. Zhang et al. note that one of the most widely discussed and adopted methods in recent years is the flipped classroom [2]. According to M. Güler, M. Kokoç, S. Önder Bütüner, this involves reversing the traditional roles of teacher and students: instead of receiving knowledge passively during class time [3]. As noted by Y. Hao, students discover new content independently, generally using multimedia teaching tools, and devote class time to problem-solving situations and interactive activities [4]. F. Jiang, W. Zhang, F. F. Jin et al. note that this learning model places the student at the heart of the learning process, and has many advantages, particularly in terms of motivation and academic success [5].

However, over and above the benefits linked to the acquisition of new knowledge, studies suggest that the flipped classroom could have a considerable impact on the development of students' metacognitive skills [6]. According to A. Popandopulo, A. Kudysheva, N. Fominykh et al. [7], metacognition refers to the ability to reflect on one's own cognitive processes, to become aware of one's learning strategies, and to adjust and regulate them. R. M. Abdelrahman affirmed that these skills include planning tasks, monitoring learning progress and evaluating the strategies used [8]. J. H. Flavell concluded that metacognition development in students is essential, as it can make them more autonomous by taking a critical perspective on their learning, as well as being better able to solve problems and adapt to new situations [9].

In this sense, S. Han suggests that the flipped classroom can provide an environment conducive to the development of these skills [10]. According to V. S. G. Silverajah, S. L. Wong, A. Govindaraj et al. [11], this model encourages self-regulation and awareness of the learning process by encouraging students to take ownership of the content before the class and to collaborate actively during face-to-face sessions. It has been suggested by D. Wu, X. Dong [12] that by taking greater responsibility for their own learning, students are encouraged to organise their work more effectively, evaluate the effectiveness of their strategies and adjust their methods in response to the challenges they encounter. For example, during classroom sessions, they are often confronted with activities that encourage them to reflect on their understanding and adjust their approaches, in cooperation with their peers and with the support of the teacher [10].

J. M. Limueco and M. S. Prudente [13] conducted a study on the relationship between the flipped classroom and metacognitive awareness, which is a relevant and still underexplored area of research. Indeed, while the flipped classroom is frequently studied in terms of its impact on student engagement and performance, it is crucial to better understand how it could specifically strengthen metacognitive skills, which are essential for sustainable and effective learning, as mentioned by R. Khosravi, A. Dastgoshadeh, K. Jalilzadeh [14]. M. Kapur, J. Hattie, I. Grossman et al.

[15] stated this is even more important in the context of secondary education, where students are in the midst of developing their capacity for autonomy and regulating their learning.

The aim of this study is to understand how the flipped classroom influences students' metacognitive awareness. Using the Metacognitive Awareness Inventory (MAI) scale, this article explores the extent to which this pedagogical approach can help students become aware of their cognitive processes and better manage their learning.

By examining students' metacognitive skills, such as planning, monitoring and evaluating their learning processes, we pose the following question: does the flipped classroom promote better regulation of learning and can improve students' academic performance through the development of their metacognitive skills?

This study highlights the importance of metacognition in student learning through the integration of the flipped classroom, which could play a key role in strengthening these skills and improving students' academic results.

## Literature Review

At present, the term 'metacognition' is commonly used to refer to individuals' thinking processes [16]. However, of the other definitions in the literature, the one most frequently mentioned is that metacognition refers to 'the ability of an individual to elicit information about his or her cognitive structure and to organise it' [17, 18].

According to B. A. Blummer, J. M. Kenton [20], teachers must know and understand the different thinking skills that underpin learners' competences. Ö. Demir and A. Doğanay [20] affirm that individuals with metacognitive skills perceive learning processes, control these processes, plan their own learning, monitor learning processes, organise their learning methods and finally move on to self-assessment.

Research on metacognition analyses what people think about their own cognition (metacognitive knowledge) and how people actually monitor and control their cognition (metacognitive skills). There are many models of metacognitive skills in relationship to other concepts namely self-regulation and metacognitive awareness, each with slight theoretical variations and different terminology [21, 22, 23, 24].

As stated by C. H. Padmanabha [25], developing metacognitive skills during learning allows students to evaluate their own understanding, making the learning process more effective. This can also increase motivation to learn. It also improves students' ability to think by enhancing their metacognitive skills, critical thinking [26] and creative thinking [27]. However, the borderlines between metacognitive skills and strategies are ambiguous in both definition and composition. C. Gama [28] uses the term metacognitive strategies for the conscious and intentional use of specific methods, and cognitive strategies to define refined strategies that are used automatically and unconsciously according to specific needs.

In addition, M. Lebrun and J. Lecoq argue that the flipped classroom is a disruption of traditional teaching tasks [29], making it possible to study content at a distance well in advance of the classroom session, and to carry out learning activities in collaboration with peers in the classroom, as noted by J. Bishop and M. Verleger [30]. Thus, A. D. Mazur, B. Brown, M. Jacobsen [31] showed that the flipped classroom requires the learner's involvement by reading the course and preparing questions before getting to it in the classroom.

According to A. Rutkienė, I. G. Kaçar, E. Karakuş et al. [32], the flipped classroom focuses not only on the use of digital resources, but on the ambition, motivation and engagement of learners with the teaching-learning process. Ò. Flores, I. Del-Arco, P. Silva [33] showed that through flipped classroom learning, learners develop abilities such as autonomy and critical thinking and improve their learning processes through collaborative learning methods. R. Martínez-Jiménez and M. C. Ruiz-Jiménez [34] highlight that collaborative work is a fundamental element for successful learning through the flipped classroom either in the classroom or at home. Similarly, the flipped classroom helps to improve learner motivation, engagement and satisfaction during the teaching-learning process [35, 36]. T. Roach [37] points out that the practice of the flipped classroom makes it possible to achieve a good relationship between learners and their teacher.

## Methodology

***Characteristics of the Sample***

This study was carried out in two Moroccan secondary schools in the Casablanca-Settat academic region. We opted for simple random sampling, as the study population was composed of students with more or less similar characteristics.

Table 1 shows the characteristics of the sample, which comprised a total of 212 students: 112 females (52.83%) and 100 males (47.17%). The average age of the students was 15.64 (15.67 for females and 15.61 for males). The sample was divided into two experimental groups, one of which was designated as the experimental group and the other as the control group.

Table 1

Sample characteristics by group, gender, number of participants and age

| Group | Gender | Number of participants | | Age |
|---|---|---|---|---|
| | | N | % | |
| Experimental | Male | 51 | 24.06% | 15.84 |
| | Female | 59 | 27.83% | 15.54 |
| | Total | 110 | 51.89% | 15.68 |
| Control | Male | 49 | 23.11% | 15.37 |
| | Female | 53 | 25.00% | 15.81 |
| | Total | 102 | 48.11% | 15.60 |
| Total | Male | 100 | 47.17% | 15.61 |
| | Female | 112 | 52.83% | 15.67 |
| | Total | 212 | 100.00% | 15.64 |

***Measuring Instruments and Data Analysis***

The Metacognitive Awareness Inventory (MAI) is a psychometric tool designed to assess an individual's level of metacognitive awareness, i.e. their ability to reflect on their own cognitive processes. Developed by G. Schraw and R. S. Dennison [38], this scale comprises 52 items measuring two main dimensions: knowledge about cognition (understanding of one's cognitive strengths and weaknesses, as well as effective strategies) and regulation of cognition (ability to plan, monitor and evaluate one's cognitive performance). The results obtained enable us to measure the development of students' metacognitive skills and the effectiveness of their learning.

Knowledge about cognition:

- Declarative Knowledge (contains 8 statements) is used to measure the knowledge required by the learner to understand information or skills and abilities. This knowledge, acquired through presentations, demonstrations or discussions, etc.
- Procedural Knowledge (contains 4 statements) measures the ability to apply knowledge to carry out a procedure or process. It assesses mastery of learning strategies and the ability to know when and how to use them in various situations.
- Conditional Knowledge (contains 5 statements) measures the ability to determine when specific processes or skills need to be applied. It assesses mastery of when and why to use learning procedures, as well as the application of declarative and procedural knowledge under specific conditions.

Regulation of cognition:

- Planning (contains 7 statements), to measure the ability to set clear objectives and allocate learning resources effectively.
- Information Management Strategies (contains 10 statements) to measure the skills and strategies used to process information more effectively, such as organising, elaborating, summarising, etc.
- Comprehension Monitoring (contains 7 statements) used to evaluate learning through formative assessment, and the effectiveness of the strategies used.
- Debugging Strategies (contains 5 statements) used to measure the effectiveness of strategies used to correct errors in comprehension and performance (self-regulation).
- Evaluation (contains 6 statements) used to measure performance, and the effectiveness of the strategy used after a learning sequence (self-assessment).

The response scale is binary, with the 52 statements offering two opposing answers ('true' or 'false'). One point is awarded if the answer is 'true', and 0 points if the answer is 'false'. Each criterion is scored by adding up the points obtained.

The data collected from the measuring instrument were analysed using IBM SPSS Statistics software, version 23. We used descriptive analysis methods and parametric statistical tests.

***Experimentation***

The aim of the study was to assess the impact of the flipped classroom approach on students; metacognitive skills. To do this, the MAI (Metacognitive Awareness Inventory) questionnaire was administered to two groups: an experimental group who followed their course using the flipped classroom approach and a control group who received traditional teaching. The experiment lasted one semester (4 months).

Comparison of the results will make it possible to analyse the effects of the flipped classroom on the development of metacognitive skills.

## Results

### *Knowledge about Cognition*

Table 2

Descriptive statistics for Knowledge about Cognition scores on the MAI scale for the experimental and control groups

<table>
<tr><th>Group</th><th colspan="2">Test</th><th>D.K</th><th>P.K</th><th>C.K</th></tr>
<tr><td rowspan="8">Experimental</td><td colspan="2">N</td><td>109</td><td>109</td><td>109</td></tr>
<tr><td colspan="2">Mean</td><td>6.40</td><td>3.19</td><td>4.03</td></tr>
<tr><td rowspan="2">95% confidence interval for Mean</td><td>Lower bound</td><td>6.19</td><td>3.03</td><td>3.86</td></tr>
<tr><td>Upper bound</td><td>6.46</td><td>3.36</td><td>4.19</td></tr>
<tr><td colspan="2">Median</td><td>7.00</td><td>3.00</td><td>4.00</td></tr>
<tr><td colspan="2">Variance</td><td>1.317</td><td>.768</td><td>.768</td></tr>
<tr><td colspan="2">SD</td><td>1.148</td><td>.876</td><td>.876</td></tr>
<tr><td rowspan="8">Control</td><td colspan="2">N</td><td>103</td><td>103</td><td>103</td></tr>
<tr><td colspan="2">Mean</td><td>6.39</td><td>2.21</td><td>2.55</td></tr>
<tr><td rowspan="2">95% confidence interval for Mean</td><td>Lower bound</td><td>6.18</td><td>2.00</td><td>2.34</td></tr>
<tr><td>Upper bound</td><td>6.60</td><td>2.43</td><td>2.76</td></tr>
<tr><td colspan="2">Median</td><td>7.00</td><td>2.00</td><td>2.00</td></tr>
<tr><td colspan="2">Variance</td><td>1.161</td><td>1.209</td><td>1.171</td></tr>
<tr><td colspan="2">SD</td><td>1.078</td><td>1.099</td><td>1.082</td></tr>
</table>

*Note.* D.K: Declarative Knowledge; P.K: Procedural Knowledge; C.K: Conditional Knowledge

Analysis of the results in Table 2 shows that the flipped classroom had a significant impact on procedural knowledge (P.K) and conditional knowledge (C.K), while declarative knowledge (D.K) remained stable.

In fact, the means of P.K (3.19 vs 2.21) and C.K (4.03 vs 2.55) were significantly higher in the experimental group, with non-overlapping confidence intervals, confirming a real progression. In addition, the higher medians in this group indicate a general improvement in applied skills. On the other hand, D.K was not affected by the flipped classroom intervention, with almost identical means (6.40 vs. 6.39) and similar distributions. This suggests that the experience mainly strengthened the ability to use and adapt knowledge rather than to memorise it.

These results indicate that the intervention encouraged more effective cognitive strategies, reinforcing the participants' autonomy in their learning.

Table 3

Shapiro-Wilk normality test for MAI scale scores

| Metacognitive dimensions | Group | Statistic | df | Sig. |
|---|---|---|---|---|
| Declarative Knowledge | Experimental | .890 | 109 | .000 |
| | Control | .902 | 103 | .000 |
| Procedural Knowledge | Experimental | .794 | 109 | .000 |
| | Control | .914 | 103 | .000 |
| Conditional Knowledge | Experimental | .836 | 109 | .000 |
| | Control | .923 | 103 | .000 |

The Shapiro-Wilk test reveals that all the p-values are less than 0.05, which means that the distributions of MAI scores do not follow normality in the two groups and for all the variables. Since the normality hypothesis is rejected, it is preferable to use non-parametric statistical tests to compare the groups (Table 3).

Table 4

Results of the Mann-Whitney test for comparison of groups.

| Statistics tests | Declarative Knowledge | Procedural Knowledge | Conditional Knowledge |
|---|---|---|---|
| Total N | 212 | 212 | 212 |
| Mann-Whitney U | 5482.000 | 2873.000 | 1767.500 |
| Wilcoxon W | 10838.000 | 8229.000 | 7123.500 |
| Test Statistic | 5482.000 | 2873.000 | 1767.500 |
| Standard Error | 427.459 | 429.965 | 433.880 |
| Standardised Test Statistic | -.308 | -6.374 | -8.864 |
| Asymptotic Sig. (2-sided test) | .758 | .000 | .000 |

Table 4 shows the results of the Mann-Whitney U test comparing the experimental and control groups. For declarative knowledge (D.K), the p-value = .758 (>. 05) indicates that there was no significant difference between the two groups. The flipped classroom therefore had no influence on this dimension. On the other hand, for procedural knowledge (P.K) and conditional knowledge (C.K), the p-values are .000, i.e. less than .05. This means that there was a significant difference between the groups, suggesting that the intervention improved these skills. Thus, flipped classroom learning had a significant impact on P.K and C.K, but no significant effect on D.K.

Table 5

Results of MANOVA analysis (Multivariate test for the effect of group on metacognitive knowledge

| Effect | | Value | F | Hypothesis df | Error df | Sig. |
|---|---|---|---|---|---|---|
| Intercept | Pillai's Trace | .980 | 3372.509[b] | 3.000 | 208.000 | .000 |
| | Wilks' Lambda | .020 | 3372.509[b] | 3.000 | 208.000 | .000 |
| | Hotelling' Trace | 48.642 | 3372.509[b] | 3.000 | 208.000 | .000 |
| | Roy's Largest Root | 48.642 | 3372.509[b] | 3.000 | 208.000 | .000 |
| Group | Pillai's Trace | .459 | 58.826[b] | 3.000 | 208.000 | .000 |
| | Wilks' Lambda | .541 | 58.826[b] | 3.000 | 208.000 | .000 |
| | Hotelling' Trace | .848 | 58.826[b] | 3.000 | 208.000 | .000 |
| | Roy's Largest Root | .848 | 58.826[b] | 3.000 | 208.000 | .000 |

*Note*. a. Plan: Constant + group; b. Exact statistics

Table 5 shows the results of the MANOVA test used to analyse whether the 'Group' factor has a significant effect on all the dependent variables (declarative, procedural and conditional knowledge).

The results show that the values of the multivariate statistics (Pillai's Trace, Wilks' Lambda, Hotelling's Trace and Roy's Largest Root) are all associated with a *p*-value of .000, i.e. less than .05. This means that there is an overall significant difference between the groups on all three types of knowledge. Thus, flipped classroom learning has a significant effect on participants' metacognitive knowledge, confirming the previous results of the Mann-Whitney tests.

***Regulation of Cognition***

Table 6

Descriptive statistics on scores for metacognitive strategies on the MAI scale for the experimental and control groups

| Group | Test | | P | I.M.S | C.M | D.S | E |
|---|---|---|---|---|---|---|---|
| Experimental | N | | 109 | 109 | 109 | 109 | 109 |
| | Mean | | 5.57 | 8.07 | 6.40 | 4.52 | 4.30 |
| | 95% confidence i nterval for Mean | lower bound | 5.35 | 7.82 | 6.26 | 4.41 | 4.11 |
| | | upper bound | 5.79 | 8.32 | 6.55 | 4.64 | 4.50 |
| | Median | | 6.00 | 8.00 | 7.00 | 5.00 | 4.00 |
| | Variance | | 1.322 | 1.754 | .595 | .381 | 1.046 |
| | SD | | 1.150 | 1.324 | .771 | .618 | 1.023 |
| Control | N | | 103 | 103 | 103 | 103 | 103 |
| | Mean | | 4.13 | 6.20 | 3.64 | 2.56 | 3.93 |
| | 95% confidence interval for Mean | lower bound | 3.84 | 5.90 | 3.39 | 2.35 | 3.69 |
| | | upper bound | 4.41 | 6.50 | 3.89 | 2.77 | 4.17 |
| | Median | | 4.00 | 6.00 | 4.00 | 2.00 | 4.00 |
| | Variance | | 2.092 | 2.360 | 1.605 | 1.150 | 1.476 |
| | SD | | 1.446 | 1.536 | 1.267 | 1.073 | 1.215 |

*Note.* P: Planning; I.M.S: Information Management Strategies; C.M: Comprehension Monitoring; D.S: Debugging Strategies; E: Evaluation

The results in Table 6 show marked differences between the experimental and control groups on the different dimensions of the scale. The experimental group had higher means on all dimensions, particularly Planning (5.57 vs. 4.13), Information Management Strategies (8.07 vs. 6.20) and Comprehension Monitoring (6.40 vs. 3.64). These differences are confirmed by the confidence intervals, which do not entirely overlap, suggesting a real effect of integrating the flipped classroom. In addition, the Evaluation dimension (4.30 vs. 3.93) showed fairly high means.

The higher medians in the experimental group reinforced this effect, indicating better overall performance after the intervention. On the other hand, the variances and standard deviations were generally lower in the experimental group, suggesting greater homogeneity of responses after the intervention. These results suggest that flipped classroom learning had a positive impact on the development of metacognitive strategies, in particular planning, information management and comprehension monitoring.

Table 7

Shapiro-Wilk normality test for metacognitive strategies

| | Group | Statistic | df | Sig. |
|---|---|---|---|---|
| Planning | Experimental | .892 | 109 | .000 |
| | Control | .948 | 103 | .000 |
| Information Management Strategies | Experimental | .919 | 109 | .000 |
| | Control | .940 | 103 | .000 |

| | | | | |
|---|---|---|---|---|
| Comprehension Monitoring | Experimental | .736 | 109 | .000 |
| | Control | .945 | 103 | .000 |
| Debugging Strategies | Experimental | .696 | 109 | .000 |
| | Control | .920 | 103 | .000 |
| Evaluation | Experimental | .903 | 109 | .000 |
| | Control | .928 | 103 | .000 |

The *p*-values (Sig. = .000) for all variables are less than .05, indicating that the data do not follow a normal distribution in the two groups (experimental and control) (Table 7). The absence of normality implies the use of non-parametric tests.

Table 8

Results of the Mann-Whitney test for the comparison of metacognitive strategies between groups

| Tests | P | I.M.S | C.M | D.S | E |
|---|---|---|---|---|---|
| Total N | 212 | 212 | 212 | 212 | 212 |
| Mann-Whitney U | 2536.500 | 2053.500 | 460.500 | 827.500 | 4574.500 |
| Wilcoxon W | 7892.500 | 7409.500 | 5816.500 | 6183.500 | 9930.500 |
| Test Statistic | 2536.500 | 2053.500 | 460.500 | 827.500 | 4574.500 |
| Standard Error | 437.978 | 439.264 | 437.275 | 432.346 | 430.079 |
| Standardised Test Statistic | -7.025 | -8.104 | -11.784 | -11.070 | -2.416 |
| Asymptotic Sig. (2-sided test) | .000 | .000 | .000 | .000 | .016 |

*Note.* P: Planning; I.M.S: Information Management Strategies; C.M: Comprehension Monitoring; D.S: Debugging Strategies; E: Evaluation

Table 8 shows the results of the Mann-Whitney U test used to compare the experimental and control groups. The p-values (Asymptotic Sig.) show that the differences between the groups are significant for all the metacognitive strategies, with values below 0.05. More precisely:

- P (Planning), I.M.S (Information Management Strategies), C.M (Comprehension Monitoring) and D.S (Debugging Strategies) show *p*-values of 0.000, confirming marked differences between the groups.
- E (Evaluation) has a *p*-value of 0.016, suggesting a less marked but still significant difference.

The negative Standardised Test Statistic values show that the experimental group obtained higher scores than the control group, confirming a positive effect of flipped classroom learning on metacognitive strategies.

Table 9

Results of the MANOVA test (Multivariate test) for the effect of group on metacognitive strategies

| Effect | | Value | F | Hypothesis df | Error df | Sig. |
|---|---|---|---|---|---|---|
| Intercept | Pillai’s Trace | .987 | 3208.034[b] | 5.000 | 206.000 | .000 |
| | Wilks’ Lambda | .013 | 3208.034[b] | 5.000 | 206.000 | .000 |
| | Hotelling’ Trace | 77.865 | 3208.034[b] | 5.000 | 206.000 | .000 |
| | Roy’s Largest Root | 77.865 | 3208.034[b] | 5.000 | 206.000 | .000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Group | Pillai's Trace | .786 | 151.040b | 5.000 | 206.000 | .000 |
| | Wilks' Lambda | .214 | 151.040b | 5.000 | 206.000 | .000 |
| | Hotelling' Trace | 3.666 | 151.040b | 5.000 | 206.000 | .000 |
| | Roy's Largest Root | 3.666 | 151.040b | 5.000 | 206.000 | .000 |

*Note.* a. Plan: Constant + group; b. Exact statistics

Table 9 presents the results of the MANOVA (Multivariate Analysis of Variance) test used to assess whether the 'Group' factor had a significant influence on all the dependent variables (metacognitive strategies).

The results show that all the multivariate statistics (Pillai's Trace, Wilks' Lambda, Hotelling's Trace and Roy's Largest Root) have p-values of .000, less than .05. This means that the group effect is statistically significant for all the metacognitive strategies. The group effect was particularly strong with a Pillai's Trace value = .786, indicating that 78.6% of the variance in metacognitive strategies was explained by belonging to the experimental or control group. These results confirm that flipped classroom learning had a significant impact on improving students' metacognitive strategies.

***The Correlation between 'Knowledge about Cognition' and 'Regulation of Cognition'***

Table 10

Spearman correlation between Knowledge about Cognition and Regulation of Cognition

| Control variables | | | Knowledge about Cognition | Regulation of Cognition |
|---|---|---|---|---|
| Rho de Spearman | Knowledge about Cognition | Correlation Coefficient | 1,000 | ,530** |
| | | Sig. (2-tailed) | . | ,000 |
| | | N | 212 | 212 |
| | Regulation of Cognition | Correlation Coefficient | ,530** | 1,000 |
| | | Sig. (2-tailed) | ,000 | . |
| | | N | 212 | 212 |

*Note.* **. Correlation is significant at the 0.01 level (2-tailed).

Analysis of the Spearman correlations between knowledge of cognition and regulation of cognition shows a correlation coefficient of 0.530 ($p$ = 0.000). This result indicates a moderate and significant positive correlation between these two variables. In other words, students with better knowledge of cognition also tend to regulate their cognitive processes better. The $p$-value ($p < 0.01$) confirms that this correlation is highly significant, eliminating the risk that this relationship is due to chance (Table 10).

Table 11

Partial correlation between knowledge and regulation of cognition

| | | | Knowledge about Cognition | Regulation of Cognition |
|---|---|---|---|---|
| Group | Knowledge about Cognition | Correlation Coefficient | 1,000 | ,162 |
| | | Sig. (2-tailed) | . | ,019 |
| | | N | 0 | 209 |
| | Regulation of Cognition | Correlation Coefficient | ,162 | 1,000 |
| | | Sig. (2-tailed) | ,019 | . |
| | | N | 209 | 0 |

Analysis of the partial correlation between knowledge of cognition and regulation of cognition shows a correlation coefficient of 0.162 with a *p*-value of 0.019. This correlation is weak but significant ($p < 0.05$), suggesting a moderate positive relationship between these two variables after control by group (experimental or control) as an influential factor. This means that, although knowledge about cognition is linked to its regulation, this relationship is less marked when other variables are taken into consideration.

## Discussion

First, the aim of this research is to understand better whether the flipped classroom influences students' metacognitive awareness. To do this, we opted for the Metacognitive Awareness Inventory (MAI) scale, and two groups of students were selected to carry out the experiment.

Our initial results show that the flipped classroom had a significant impact on procedural knowledge (P.K) and conditional knowledge (C.K), while declarative knowledge (D.K) remained stable. Similarly, the results of the Mann-Whitney U test comparing the two groups: experimental and control. For declarative knowledge (D.K), the *p*-value = .758 (> .05) indicates that there was no significant difference between the two groups. The flipped classroom therefore had no influence on this dimension.

However, for procedural knowledge (P.K) and conditional knowledge (C.K), the *p*-values were .000, i.e. less than .01. This means that there was a significant difference between the groups, suggesting that our flipped classroom approach improved these skills. Therefore, flipped classroom learning had a significant effect on P.K and C.K, but no effect on D.K.

E. A. Vliet, J. C. Winnips, N. Brouwer have suggested that the flipped classroom can have a significant effect on the dimensions of procedural and conditional knowledge [39]. Procedural knowledge (P.K) refers to the ability of students to apply their knowledge in tasks, often acquired through experience and applied in real contexts [39]. In the flipped classroom, students are encouraged to become actively involved in practical exercises, problem-solving or role-playing, which help them to develop their academic skills [40]. The results obtained by J. Liu, Z. Wu, Y-Z. Lan, W-J. Chen et al., indicate that the flipped classroom encourages active learning and enables students to work independently, which leads to a significant improvement in procedural knowledge [41].

At the same time, conditional knowledge (C.K), which is the ability to know when and why to use certain strategies or knowledge in a particular context, seems to be positively linked to the flipped classroom [42]. C.K will enable students to better organise their learning outside the classroom. O. P. Amolloh, G. K. Lilian, K. G. Wanjiru have shown that students develop a better understanding of the conditions and contexts in which certain strategies or approaches are most relevant [43].

However, declarative knowledge (D.K), which is related to the memorisation of facts, rules and theoretical concepts, seems to have changed little when linked to the flipped classroom, according to S. B. Adeyemi, E. N. Cishe [44]. Also, R. Schlag, K. Stegmann, M. Sailer show that this negative association could be due to the fact that it does not necessarily focus on the accumulation of theoretical or factual knowledge [45]. R. Plesec Gasparic, M. Glavan, M. Žveglič Mihelič, M. Valenčič Zuljan suggest that, despite the effectiveness of the flipped classroom in reinforcing the understanding and application of knowledge, it does not completely replace more traditional teaching methods that favour the memorisation and assimilation of declarative knowledge [46].

Overall, the results suggest that the flipped classroom has a more significant effect on skills related to the application and management of knowledge in specific contexts. Nevertheless, declarative knowledge seems to require pedagogical approaches more focused on memorisation.

Our second result relates to the analysis of data from the MANOVA test, enabling us to assess whether the 'Group' factor has a significant effect on students' metacognitive knowledge. The aim is to examine whether flipped classroom learning influences these different dimensions of metacognition, and to analyse these results in the light of previous research.

The data obtained show that the multivariate statistical tests used (Pillai's Trace, Wilks' Lambda, Hotelling's Trace and Roy's Largest Root) all have a $p$-value of .000, below the threshold of .01. This represents a significant difference between the groups with regard to the three metacognitive parameters. Thus, flipped classroom learning appears to have a positive effect on the development of students' metacognitive knowledge.

These results are in line with previous research that has confirmed the effect of the flipped classroom on students' learning and metacognitive knowledge. The studies of M. Algayres, E. Triantafyllou [47] and J. Barenberg and S. Dutke [48] have shown that the flipped classroom encourages active learner involvement, which leads to better structuring of knowledge. In addition, C. Gillette, M. Rudolph, C. Kimble et al. [49] have shown that this approach improves students' metacognitive thinking by giving them more opportunities to manage their own learning.

Our findings are consistent with the research by L. Hsu and S. Hsieh [50] and C. A. Bredow, P. V. Roehling, A. J. Knorp et al. [51], who have shown that the flipped classroom stimulates critical thinking and encourages students to actively mobilise their prior knowledge to solve problems, which is particularly conducive to the development of procedural and conditional knowledge.

However, despite the results obtained, it is wise to qualify the effectiveness of flipped classroom learning in developing students' metacognitive knowledge [52]. Indeed, some research points out that this approach does not guarantee a significant improvement in metacognition and may even pose significant pedagogical challenges [53]. S. Burgoyne and J. Eaton [54] warn of the risks of excessive cognitive load in students with low autonomy, which can hinder the development of procedural and conditional knowledge.

Our third result, which concerns the analysis of Spearman correlations between cognition knowledge and cognition regulation, shows a correlation coefficient of .530 ($p$ = .000). The same is true for the partial correlation between knowledge of cognition and regulation of cognition, which showed a correlation coefficient of .162 with a $p$-value of .019.

These results thus qualify the idea of a systematic and strong link between these two aspects of metacognition, calling into question certain hypotheses according to which better knowledge about cognition would automatically lead to better cognitive regulation [55]. This is in line with the conclusions of certain research studies by C. M. A. Gomes, H. F. Golino, I. G. Menezes et al. [56] and A. Efklides [57], who emphasised that metacognitive knowledge does not necessarily translate into an increased ability to regulate learning [58]. Thus, a more in-depth approach taking into account other contextual and individual factors may be necessary to better understand the mechanisms underlying this relationship [59].

## Limitations

Despite the results obtained, it is wise to mention certain limitations of our research in order to guide future studies. Although our measurement instrument has psychometric qualities, it would have been preferable to adopt other qualitative protocols in order to obtain more data and, consequently, to make our results more exhaustive.

Regarding our study sample, it would have been preferable not to limit ourselves to just three schools, but to include several in the Casablanca-Settat academic region, in order to better generalise the results obtained to the context of our research.

Finally, regarding the object of the research itself, numerous studies have emphasised that the evaluation of metacognitive components remains a complex process [60, 61, 62]. Hence the importance of using robust measurement instruments to achieve the defined research objectives.

## Conclusion

The aim of this study was to analyse the impact of the flipped classroom on students' metacognitive awareness, by exploring its effects on the different dimensions of metacognitive knowledge. The results show that this teaching approach particularly favours the development of procedural and conditional knowledge, while declarative knowledge seems to be less affected. These findings are in line with existing research, highlighting the value of the flipped classroom in enhancing students' active engagement and ability to apply their knowledge in problem situations.

However, the relationship between knowledge of cognition and the regulation of cognition appears to be more nuanced, inviting further study of the underlying mechanisms. Furthermore, although the flipped classroom has many advantages, its effectiveness depends on a number of factors, including student autonomy and the support systems put in place. Future research could therefore explore how this approach can be adapted to optimise learning in all dimensions of metacognition and respond to the challenges it may present in different educational contexts.

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