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Does the Jigsaw method improve motivation and self-regulation in vocational high schools?

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Abstract

Although much has been written about the beneficial effects of the Jigsaw method, little is known about how it affects students' motivation and self-regulation processes. In this study, we tested its effects on students' trajectories of autonomous mathematics motivation and academic self-regulation. We also examined whether these effects could be moderated by the students’ cooperative attitudes and initial mathematics achievement level. 4,698 students from French vocational high schools participated in the study over two years. They were divided into three groups: 1,641 were assigned to a cooperative learning condition with the Jigsaw method, 1,602 to a weakly structured cooperative learning condition, and 1,455 to a business-as-usual learning condition. Self-reported mathematics motivation, academic self-regulation, and cooperative attitudes were collected three times during the study. Overall, the multilevel growth model results indicate a general decline in students’ motivation and self-regulation, and student-reported cooperative attitudes did not moderate these effects. However, the trajectories of motivation and self-regulation differed by condition for low-achieving students. While these trajectories decreased over time amongst low-achieving students in the Jigsaw method condition and in the weakly structured cooperation condition, they were stable in the business-as-usual learning condition. These results provide a new perspective since they seem to question the implementation conditions of the Jigsaw method for low-achieving students.

Keywords: cooperative learning, Jigsaw method, motivation, self-regulation, vocational high school, multi-level growth analysis

Does the Jigsaw method improve motivation and self-regulation in vocational high schools?

For many years, research on the development of academic motivation and self-regulation during adolescence has focused on educational practices that contribute to student success (Dignath & Veenman, 2020; Jansen et al., 2019; Lazowski & Hullman, 2016). Early on, group work methods also occupied much of the scientific literature (e.g., Slavin, 1980), but little is known about the impact of cooperative learning environments on students' trajectories of academic motivation and self-regulation. Among the various forms of cooperative learning, we are particularly interested in the Jigsaw method, in which cooperation is structured by working first individually, then in expert groups, then in so-called "jigsaw groups" in which students who are experts in different parts of the work come together to achieve complete knowledge of a subject (Aronson & Patnoe, 2011). The results of the few studies that have analyzed the effects of the Jigsaw method on academic motivation are far from consensual (Berger & Hänze, 2009; Hänze & Berger, 2007; Law, 2011; Sanaie et al., 2019), and even fewer studies investigated long-term and large-scale effects (Roseth et al., 2019; Souvignier & Kronenberger, 2007). Yet, since it structures student interactions by reinforcing positive interdependence and individual responsibilities (Johnson et al., 2009), the Jigsaw method should reduce known adverse effects in group work (e.g., social loafing, retention of information in intragroup competition), and improve students' engagement in academic tasks and co-construction of their knowledge. This study aims to address these gaps and to clarify the effects of the Jigsaw method by investigating the trajectories of autonomous motivation in mathematics and academic self-regulation of students in vocational high schools, who have received little attention in the literature to date. It has been observed that lack of motivation to learn and self-regulation difficulties are prevalent among vocational high school students (De Stavenga et al., 2006; Slaats et al., 1999), especially in the French system (Desombre et al., 2017; Pourcelot, 2017).

From Cooperative Learning to the Jigsaw Method

Cooperative Learning as a Learning Context

Social interactions have been often presented as essential to effective learning. Thus, cooperative learning, in which students interact with each other in order to learn, is at the center of educational thinking as an alternative pedagogy to individual learning. Two key mechanisms to watch out for appear to stand out from the thousands of studies that have focused on the effectiveness of cooperative learning. First, a working group is made up of several positively interdependent members (Deutsch, 1949; Johnson & Johnson, 2009), meaning that two or more individuals come together and work as a team to achieve a common goal. The actions of group members are positively interrelated and the common goal can only be achieved if all group members contribute to the task. A second mechanism is essential to ensure a good learning experience in cooperative learning: the exercise of individual responsibility and accountability. Since each contribution is unique and cannot replace the others, all members of the group become essential to the achievement of the common goal (Slavin, 1980). Without individual accountability and responsibility, the contribution of each student to the task could become unequal and a social loafing phenomenon could take hold in the group, or in some of its members (Butera & Buchs, 2019; Deutsch, 1949; Topping et al., 2017). Consequently, strong positive interdependence combined with individual accountability and responsibility are essential for optimizing cooperation and improving the learning of all students in cooperative learning as opposed to competitive or individual learning (Johnson et al., 1981; Johnson & Johnson, 1987; Roseth et al., 2008; Stanne et al., 1999).

Even though these two mechanisms are widely acknowledged, some researchers have stressed that they may not be enough to guarantee the positive influence of cooperative learning on students' academic achievement. While the effectiveness of cooperative learning depends on positive interdependence and individual accountability and responsibility, other practices and behaviors should be promoted such as encouraging facilitative and positive interactions between students, developing students' cooperative skills and promoting their reflection on group functioning (Johnson & Johnson, 2009). Although there is no consensus, some authors have suggested that the Jigsaw method may be the most effective cooperative learning method to activate these levers (Aronson, 1978).

The Jigsaw Method

The Jigsaw method organizes cooperation by reinforcing both the positive interdependence between students and individual accountability and responsibility within the group. Positive interdependence is structured through the knowledge and materials necessary to achieve the group's goal (knowledge and resource interdependencies). Meanwhile, each student's individual responsibility is required to fulfill the need to communicate all knowledge to the group in order to achieve the common goal. When students work cooperatively with the Jigsaw method, the academic task is divided into three stages (Aronson & Patnoe, 2011). In the first stage, students begin the activity with individual work. Each student works on assigned materials (e.g., hard copy documents, videos) to understand and summarize one or more pieces of knowledge that will constitute their *learning expertise*. Each learning expertise thus corresponds to a subtopic of the learning activity and is essential to achieve the group's goal. In the second stage, the students work in *expert groups*: those who have worked individually on the same subtopic meet and discuss what they have learned. The purpose of this stage is to prepare the students to build on their expertise in order to teach it effectively to others in their group, which will be done in the third stage: the *jigsaw* group. During this last stage, the members of the puzzle group, who have each worked on a different part of the activity, discuss their respective content and share it to achieve the group's goal, in the manner of a puzzle that will be completed by the information provided by each student. Despite its popularity based on its original objective of inclusion of students from ethnic minorities (in the USA), empirical evidence of the positive effects of the Jigsaw method on learning and academic performance is unconvincing, suggesting at best a moderately positive influence of the method. A first meta-analysis conducted by Johnson et al. (2000) found positive effects of the Jigsaw method on learners' performance compared to individualistic learning (*d* = 0.13). This result must be weighed against the one obtained in a new systematic review and meta-analysis by Cochon Drouet et al. (2023), which focused on exploring the effects of the Jigsaw method on student educational outcomes such as learning (including both achievement and motivation), but also self-esteem and social relations. The authors conclude that there is considerable heterogeneity in the results of the various studies taken into account, with a weakly positive overall effect size when it comes to achievement, and no significant effect for studies looking at motivation, self-esteem or social relations. A meta-analysis recently published by Stanczak et al. (2022) found a z-score of 0.10 for the effectiveness of the Jigsaw method compared to other learning situations in five classroom experiments. These positive effects on academic performance are partly explained by the psychological processes activated by the jigsaw method. According to Slavin (2014a), in cooperative learning, students should be more motivated to learn as well as encourage others to do their work. In addition, the accomplishment felt in working in a group should allow them to make their learning even more meaningful (Johnson et al., 2014) and increase individual motivation. Johnson and Johnson (2009) also claimed that positive interdependence improves the construction of new ideas and the use of higher-level cognitive strategies. Sharing knowledge with others also improves cognitive restructuring because the student is fully engaged in the group activity.

The Jigsaw Method, Academic Motivation and Self-Regulation

Motivation and Self-Regulation in Learning Context

Academic motivation is crucial at school, since it determines students’ attitudes and behaviors towards academic tasks (Schunk & DiBenedetto, 2020). Self-determination theory can help us understand academic motivation because it provides us with a continuum that describes different types of motivation that may be more or less self-determined (Ryan & Deci, 2000, 2020). On one side of the continuum is autonomous motivation, composed of intrinsic motivation and identified regulation, meaning that students intend to perform and carry out activities for the enjoyment of doing so, or at least because they consider them to be important to achieve their personal goals. This type of motivation is more likely to occur when three basic psychological needs for competence, autonomy and interpersonal relatedness are met (Ryan & Deci, 2000). On the other side of the continuum is controlled motivation; in this case, the tasks to be carried out are associated with pressure or obligation. Controlled motivation generates negative feelings including irritability and anxiety, and is not conducive to academic success because it reduces effort and engagement (Guay & Bureau, 2018; Howard et al., 2021; Michou et al., 2014; Taylor et al., 2014), whereas autonomous motivation increases the likelihood of academic success (Cerasoli et al., 2014; Howard et al., 2021; Taylor et al., 2014). Autonomously motivated students are less prone to absenteeism or disengagement (Howard et al., 2021), are more committed to their learning, and have positive emotions towards school (Cleary & Kitsantas, 2017; Howard et al., 2021; Michou & al., 2014; Pintrich & De Groot, 1990).

Autonomously motivated students are also more likely to self-regulate (Cleary & Kitsantas, 2017; Pintrich & De Groot, 1990), which Pintrich (2000) describes as the ability to plan, monitor, control and evaluate the effectiveness of their cognition, motivation, behaviors and learning context in order to achieve their individual goals. It is an equally decisive ability for students' learning (Caprara et al., 2008; Dent & Koenka, 2016) and mediates the impact of motivation on their success (Lee et al., 2014). Self-regulation is also a key factor in academic success. While students know how to practice certain self-regulatory strategies, the correct strategies they need to succeed may differ depending on the learning context because the process of self-regulation is socially situated (Hadwin et al., 2017).

Effects of Jigsaw Method on Autonomous Motivation and Self-Regulation

By giving individual students the goal of teaching specific knowledge to the other members of the group, the Jigsaw method should encourage every student to be more interested and involved in the activity, and more attentive to their understanding of the material assigned to them (Buchs et al., 2004). Since individual goals are also extended during learning with the Jigsaw method, students' individual self-regulation as well as group regulation are essential for the accomplishment of the task (Hadwin et al., 2017). Moreno (2009) observed that students who worked in a Jigsaw group performed metacognitive activities more frequently than when learning cooperatively without the Jigsaw structure (e.g., reflection on the learning task).

However, empirical evidence of the impact of the Jigsaw method on academic motivation and self-regulation remains inconclusive. When the Jigsaw method was implemented on a short-term basis (e.g., a two-hour session), most studies did not reveal direct effects of the method on learners' autonomous motivation and self-regulation (e.g., Berger & Hänze, 2009; Hänze & Berger, 2007). Furthermore, Roseth et al. (2019), who to our knowledge conducted the only study of the learners' motivational trajectory, did not reveal any effect of the Jigsaw method on student motivation. However, they did indicate positive effects on academic achievement trajectories, especially for those students who reported positive attitudes toward cooperation. This latter point suggests that some individual characteristics may moderate the effectiveness of the Jigsaw method.

Moderating Conditions for a more Efficient Jigsaw Method

In the Jigsaw method, students require certain sociocognitive skills, such as open-mindedness, listening, and questioning, to be able to correctly convey information to the other group members and to fully benefit from each other's contributions. Students' cooperative attitudes and academic performance (results/grades) may also moderate the effects of the Jigsaw method.

Cooperative Attitudes

In contrast to individualistic attitudes, cooperative attitudes can enhance the effectiveness of cooperative learning on learners' social behaviors and achievement. Cooperative attitudes are preferences for working cooperatively, and valuing one's own work as well as the work of others (Johnson et al., 2009). Research has shown that students who report positive attitudes towards cooperation and teamwork felt closer to their peers and more supported by them (Johnson & Ahlgren, 1976). They also reported more prosocial behaviors toward their peers (Johnson et al., 2009) and were more motivated to learn (Supanc et al., 2017). In short, when students' attitudes are conducive to cooperation, the Jigsaw method could be all the more beneficial for their motivation and self-regulation. Although Roseth et al. (2019) did not find significant results on motivation, they still showed that, when using the Jigsaw method, students with high cooperative attitudes performed better academically.

Academic Performance

Berger and Hänze (2015) examined high school students' knowledge acquisition from materials in which they were not experts. Their results showed that, whatever the cognitive demand of the task given, the students whose academic performance was lower prior to the task, performed worse on the knowledge acquisition test, and the gap between low and high-performance students grew when the cognitive demand of the task was greater. Further, Deiglmayr and Schalk (2015) revealed that low performance students working in a regular Jigsaw condition performed worse on the knowledge transfer task than their more proficient peers. These results suggest that students' prior academic performance has an impact on the effectiveness of the Jigsaw method. Concerning self-perceptions of competence, Hänze and Berger (2007) showed that high school students who reported a low perception of competence in science also reported a stronger sense of competence after learning with the Jigsaw method than after direct instruction. This evidence supports the hypothesis that responsibility for task-critical information can lead students to an experience of mastery (Darnon et al., 2012). This experience would allow them to feel more legitimate in bringing their expertise to the group and consequently increase their enjoyment of academic tasks. Jigsaw method may therefore positively affect feelings of competence and self-confidence among students who feel insecure due to previously low results in this school subject, which could influence individual outcomes over time.

Program Implementation

From a more general perspective, some authors (Moreno, 2009; Roseth et al., 2019) have mentioned that for the Jigsaw method to produce the expected effects, students need to be familiar with this form of long-term learning. Indeed, it requires important skills that are not easily acquired, especially those related to group work, such as communicating accurately and resolving conflicts constructively (Johnson & Johnson, 2009). To date, implementation of this method in previous experiments has not exceeded one semester of classroom intervention (Basyah et al., 2018; Roseth et al., 2019; Souvignier & Kronenberger, 2007). Moreover, most studies have compared the Jigsaw method to “usual learning”, that is to say learning in which no instruction is specified (e.g., Roseth et al., 2019). Very few interventions have compared the Jigsaw method to weakly structured cooperative learning (i.e., with little structure to positive interdependence and individual responsibilities), with the exception of Berger and Hänze's study (2009). It is thus important to verify that the impact of the Jigsaw method does indeed come from the strong positive interdependence between the students, which is not possible by comparing the Jigsaw method to usual learning only.

In the present study, the experimental program was the first to extend the intervention period over two school years and considered students’ cooperative attitudes as a potential moderator of the effects of cooperative learning conditions on self-regulation and academic achievement. Three learning conditions are also compared: a structured cooperative learning condition with the Jigsaw method, a weakly structured cooperative learning condition, and a business-as-usual condition. This study stems from a national experiment (ProFAN) conducted in French vocational high schools from September 2017 to June 2019. The list of the 109 participating high schools was provided by the Ministry of Education. The schools included in this study belonged to ten “académies” (the educational administrative unit in France). They were chosen by the French Ministry of Education, on a voluntary basis. The schools were selected by the ministry according to the vocational tracks they offered: electricity, business and care sector services. In each school included in the study, the school principals had given their agreement, and a team of teachers had agreed to take part. Each school was assigned to one of the three learning conditions. Four learning sequences in mathematics, each lasting five to ten hours, were conducted throughout the experiment. The first two sequences took place during the first school year and the other two during the second year. The content of these sequences was in line with the students' school curriculum: the first sequence was on one-variable statistics, the second on quadratic equations, the third on polynomial functions, and the fourth on the common logarithm. The researchers and a team of professionals (i.e., inspectors, teachers) co-constructed the content and materials of the learning sequences. In all three learning conditions, the mathematics teachers had access to the themes and durations of the learning sequences and the individual assessments on an online platform. The teachers of the two cooperative learning groups (i.e., Jigsaw method and weakly structured cooperation) also had access to teaching guides for the sequences. These guides included work methods, materials and information to carry out the sequences as well as advice on supporting students during the learning process.

The three learning conditions had two things in common: the students studied the same content and the teachers had the same amount of time to teach it (see Figure 1). In both cooperative learning conditions, students were randomly assigned to groups of three to four using a dedicated digital platform, then the teacher introduced the learning topic to all students in the class. In the Jigsaw method condition, after the students were assigned to their group, the knowledge and materials (resources) needed to complete the sequence were also randomly distributed among the group members. After the expert work, the students met in their jigsaw group to produce the final objective by pooling all their knowledge. In the weakly structured cooperative learning condition, the students worked on the lesson content in groups first, then they worked on the final objective in the same groups. Finally, at the end of the sequences, in both cooperative learning conditions, the groups presented the purpose of the group work to the class and the teachers closed the sequences by reviewing the content. In the business-as-usual learning condition, the teachers were free to organize the work sequences as they wished. However, they had to respect the time constraints and have the students work on the same activities as in the other two learning conditions.

Figure 1

Objectives and Hypotheses

The present study was commissioned by the French Ministry of Education. It aimed to analyze the effects of the Jigsaw method on the evolution of vocational high school students' autonomous motivation in mathematics and self-regulation over two school years. First, we assessed whether the Jigsaw method had a beneficial impact on students' mathematics motivation and self-regulation trajectories. We expected the Jigsaw method to have a positive impact on the evolution of students' self-regulatory motivation in mathematics, compared to weakly structured cooperative learning or business-as-usual learning situations (1a). We also expected that students' academic self-regulation trajectories would be positively impacted by cooperative work in the Jigsaw method compared to the other two conditions (1b). Second, we examined the impact of moderating factors expected to play an important role on the effectiveness of the Jigsaw method: the students' cooperative attitudes and their initial mathematics performance. We expected the students who reported the strongest cooperative attitudes to have the most positive trajectories of motivation and self-regulation (2a). Concerning the students' academic performance, our approach was more exploratory and we envisaged two alternative hypotheses. The first "optimistic" hypothesis was that the Jigsaw method could be beneficial for the students with lower prior achievement since acquiring a specific expertise would motivate them to make an effort to accomplish the academic tasks required for the group (2b). The second, more "pessimistic" hypothesis was when learning content is new and complex, students with lower prior achievement could experience difficulty in taking individual responsibility and participating effectively in the co-construction of learning in the group (2c).

Materials and Method

Participants

5,226 students from 109 French vocational high schools participated in the experiment. At the beginning of the study, the majority of the students were between 16 and 17 years old (55,7 % girls). They were studying for three types of professional qualification (see Table 1): care sector services (*n* = 1,767), business (*n* = 2,197), and electricity (*n* = 1262). The number of students was similar for each condition: The Jigsaw method condition (*n* = 1,793), the weakly structured cooperative learning condition (*n* = 1,768), and the business-as-usual learning condition (n= 1,665). One of the particularities of the vocational programs is that they differ according to student gender. Among the participants in "care sector services", the vast majority were girls (94%), whereas in "electricity", the vast majority were boys (98%). In "business", the gender split was more balanced (53.76% girls; 46.24% boys). Students in each condition were unaware of the other conditions in the experiment.

Table 1

Over the two school years, longitudinal self-report data were collected three times and 4,698 students completed the questionnaire during at least one of the three times. A total of 4,282 students responded to the first measure (91.1% of the sample), 3,100 responded to the second measure (66%), 2,401 responded to the third measure (51.5%), and of these students, 1,680 responded to all three measures.

Material

Student Measures

Autonomous motivation in mathematics. Four statements from Ryan and Connell's Academic Self-Regulation Questionnaire (SRQ-A, 1989) were translated into French by Leroy et al. (2013) and the instruction was adapted for mathematics. Students responded to the following statement: When we do mathematics in class, I work because.... "I like what is being asked of me," "I want to learn new things," "I enjoy what we are doing," and "It is important for me to work on mathematics." For each statement, students gave their level of agreement on a Likert scale ranging from 1 "*totally disagree*" to 7 "*totally agree*". The more students agreed with the statements, the more autonomously motivated they reported being. Exploratory factor analyses revealed satisfactory Kaiser-Meyer-Olkin (KMO) indices for each measurement time (T1= 0.75; T2= 0.92; T3= 0.92) and high factor loadings. The internal consistency of the scale was high at all three time points ($.87 \leq \alpha \leq .88$).

Cooperative Attitudes. They were measured with ten statements adapted from a subscale of the Driskell et al. Collective Orientation Scale (2010). The students indicated their level of agreement with each item on a Likert scale ranging from 0 "*totally agree*" to 4 "*totally disagree*." The more students disagreed with the statements, the more cooperative attitudes they reported (e.g., "I prefer to complete a task from start to finish without help from others"). Exploratory factor analyses revealed considerable variability in the factor loadings, but the high KMO indices indicate a satisfactory match between the data (T1= 0.85; T2= 0.86; T3= 0.84). The internal consistency of the scale was satisfactory at all time points ($.75 \leq \alpha \leq .80$).

Initial Mathematics Level. At the first measurement point, students reported on a five-point scale their grade point average in mathematics at the end of the previous school year. Responses ranged from 0 to 4 with a score of 0 indicating an average of 0 to 4.9 out of 20, 1 corresponding to an average between 5 and 8.9, 2 an average between 9 and 12.9, 3 an average between 13 and 15.9, and 4 an average between 16 and 20[1].

Academic self-regulation. A nine-item scale inspired by the Motivated Strategies for Learning Questionnaire by Pintrich et al. (MSLQ, 1991) and based on the French translation by Jamain et al. (2020) was used. It included items that referred to students' autonomy, effort and organizational strategies. Five of the statements are literal translations of the scale and four news statements were added, such as "I try hard to finish the difficult exercises". For each statement,

[1] In the French educational system, grades range from 0 (the lowest possible grade) to 20 (the highest possible grade).

students indicated their agreement on a Likert scale ranging from 1 "*totally disagree*" to 7 "*totally agree*". The more the students agreed with the statements, the more they reported self-regulating. The exploratory factor analyses revealed high KMO indices, indicating satisfactory data adequacy (0.92 for all three times), and the factor loadings ranging emphasize a strong robustness. The internal consistency for each measurement time was high ($.88 \leq \alpha \leq .89$).

Fidelity of Implementation of Educational Interventions in Classes

A fidelity indicator for the implementation of cooperative learning conditions in mathematics was constructed from the responses to systematic interviews with pre-selected school staff members. For each school year, we considered six criteria of implementation of the Jigsaw method. The first criterion referred to the overall quality of implementation: The above-mentioned school staff had to report on how the intervention in the mathematics classes had gone. Five other criteria specific to the fidelity of the Jigsaw method followed: (1) compliance with group work, (2) not handing over material before the session, (3) compliance with the distribution of activities in the group, (4) compliance with work in expert groups, and (5) participation of all students in the Jigsaw groups. For weakly structured cooperative learning, we considered four criteria to establish implementation fidelity. Three were similar to those for the Jigsaw method condition (i.e., overall flow of the intervention during the school year, compliance with group work in the sequences, and not handing out materials before the sessions). The fourth criterion verified that there was no structured division of activities in the groups during the learning sequences. We created an average fidelity assessment over the two school years. The implementation was coded good, average, poor or unidentified.

Procedure

To collect longitudinal measures at all three measurement times, an online questionnaire was completed by the students during school hours. At the first measurement, the questionnaire was completed before the intervention began, between October and November 2017. The second questionnaire was completed during the intervention between May and June 2018, and in rare cases, in September 2018. The third questionnaire was completed after the intervention, between April and May 2019. Completion took place during school hours and one teacher per class proctored. The data obtained from these completed questionnaires were anonymized.

Statistical Analyses

Invariance of Longitudinal Measures

Prior to longitudinal analyses, the longitudinal invariance of the measures of autonomous motivation in mathematics and academic self-regulation was analyzed using the Lavaan package on R Studio version 4.0.2 (Rosseel, 2012). Assessing the temporal invariance of constructs is necessary to ensure that the temporal change observed in the longitudinal models corresponds to actual change and not temporal change in the measurement construct (Brown, 2015). In this study, the weak longitudinal invariance of the measures must be validated at a minimum (i.e., identical configurational invariance and factor loadings of manifest factors over time).

The results presented in Table 2 show that for the autonomous motivation scale, the weak longitudinal invariance model is the best fit for the measurement data. While the decrease in the maximum likelihood difference between the configural and weak invariance models is significant ($\Delta 2$ ML(48) = 29.91, $p < .001$), the RMSEA indicator for the weak model is greater than 0.06, the RMSEA decreases by 0.04 points between the configural and weak invariance models. The CFI is also very satisfactory (0.96) and does not vary. The strong invariance model fits the data less well with a CFI indicator that decreases by 0.09 points and the RMSEA that increases beyond the acceptable threshold of 0.10. For the academic self-regulation scale, the strong longitudinal invariance model is the best fit to the measurement data. While the decrease in the maximum likelihood difference between the weak invariance model and the strong invariance model is significant ($\Delta 2$ML(331) = 160.9, $p < .001$), the quality of the CFI (0.94) and RMSEA (0.051) allows us to conclude to a strong longitudinal invariance. The strict longitudinal invariance model does not fit the data correctly as the CFI decreases by .24 points and the RMSEA exceeds the acceptable threshold of .10.

Table 2

Statistical Models and Specification

To test the hypotheses, multilevel growth analyses (Snijders & Bosker, 2011) were performed on R Studio version 4.0.2 with the lme4 package (Bates et al., 2015). These models yield more robust estimates than conventional models because they are based on multiple measurement points, limiting the impact of measurement errors on the estimates. An advantage of these models is that the variance of the response variable is spread over multiple levels of analysis: within-student, between-students, and between-schools. Another advantage of the multilevel growth model is its flexibility to estimate the parameters even when an individual has missing data over time. Indeed, individuals do not need to be present at all measurement times to be retained in the analyses. Information from these incomplete cases is therefore incorporated into the iterative calculation process and leads to more accurate parameter estimates. For this purpose, the missing data must be MAR (Missing At Random) or MCAR (Missing Completely At Random). To test the MCAR hypothesis, we used Little's test (Little, 1988) which, as expected, was not significant Chi2 (1040) = 1008.64, $p = .75$. It validates the hypothesis that the mechanism explaining the missing data in the dataset is MCAR.

The modeling process was specified step by step in order to best fit the data and test our hypotheses. Models 1 to 5 aim at gradually adjusting the random part of the model. Model 1 is an unconditional growth curve model that specifies three random levels (occasions, students and schools). Model 2, adds a random slope of time at the student level. Model 3 adds a correlation between intercepts and slopes. Model 4 adds a random slope of time at the school level. Model 5 adds a correlation between intercepts and slopes at the school level. Model 6 adds our independent variables, both control variables (mathematics initial level, vocational track) and our target independent variables (learning condition and cooperation). Model 7 adds interactions between time and our target independent variables. Model 8 includes the implementation quality, while removing the learning conditions. Model 9 adds a three-way interaction between our target independent variables and time. Model 10 includes an interaction between time and mathematics initial level. Finally, Model 11 adds a three-way interaction between the learning conditions, the implementation quality and time. The significance of each model compared to the former (if nested in the latter) is obtained via the deviance decrease, which follows a Chi-square distribution with the number of supplementary parameters as number of degrees of freedom.

Results

Descriptive Analyses

Table 3 presents the means and standard deviations of students' motivation and self-regulation at the three measurement times. We observed that students' motivation in mathematics and their reported level of self-regulation decreased over the course of the experiment, particularly between times 1 and 2. This decrease accounted for 0.16 point of motivation in mathematics and 0.10 point of self-regulation between times 1 and 3. Regarding the learning conditions, the means of students' motivation in mathematics and self-regulation were not different at time 1 [motivation: $F(2,4279) = 1.70$ $p = .18$); self-regulation: $F(2,4279) = 0.05$, $p = .96$], nor at time 2 [motivation: $F(2,3044) = 1.70$, $p = .18$; self-regulation: $F(2,3097) = 0.23$, $p = .66$], nor at time 3 [motivation: $F(2,2152) = 0.45$, $p = .64$; self-regulation: $F(2,2152) = 0.32$, $p = .73$].

The descriptive results showed that students' initial mathematics level differed significantly between the three learning conditions (see Table 3). Students in the Jigsaw method condition (*M* = 2.26; *SD* = 1.09) reported a lower initial mathematics level than those in the business-as-usual condition (*M* = 2.37; *SD* = 2.11). In addition, students in these two conditions reported an initial level that was higher than those in the weakly structured cooperative learning condition (*M* = 2.11; *SD* = 1.11).

The means for cooperative attitudes were identical among the three learning conditions at time 1 and at time 2, but different at time 3 (see table 3). Students in the Jigsaw method condition reported fewer cooperative attitudes at time 3 (M = 1.85; SD = 0.58) than students in the usual learning condition (M = 1.94; SD = 0.55).

Table 3

The correlation matrix (Table 4) indicated that the three mathematics motivation measurement times were fairly highly correlated ($.50 \leq r \leq .62$), as were the three self-regulation measurement times ($.45 \leq r \leq .57$). Weaker correlations appeared between the motivation and self-regulation scores ($.23 \leq r \leq .40$) as well as between initial mathematics level and the mathematics motivation score ($.32 \leq r \leq .44$) and the self-regulation score ($.19 \leq r \leq .25$). Regardless of the measurement time, the students' self-reported cooperative attitude scores were uncorrelated or weakly correlated with the motivation and self-regulation scores.

Table 4

Based on the results in Table 5, the average implementation fidelity of the puzzle class in mathematics classes across the two grade levels was more often categorized as poor than good or average (n_{good} = 9; $n_{average}$ = 9; n_{poor} = 11). The distribution of schools across levels of implementation fidelity was more uneven in the weakly structured cooperative learning condition, with a majority categorized as having poor implementation fidelity (n_{good} = 7; $n_{average}$ = 1; n_{poor} = 14). Prior to testing the hypotheses, growth analyses were conducted to assess the effects of learning conditions by implementation quality on changes in students' autonomous mathematics motivation and self-regulation, and no differences in change between conditions by implementation quality were observed.

Table 5

Effects of the Jigsaw Method on Motivation and Self-Regulation

Unconditional Growth Models

According to the results summarized in Table 6, students' autonomous motivation in mathematics as well as their self-regulation decreased significantly over time. For every one unit increase in time, students lost an average of 0.12 points of autonomous motivation in mathematics. Finally, for a one standard deviation increase in time, students' motivation decreases by 0.06 standard deviation. Self-regulation and motivation in mathematics have a fairly similar decreasing trajectory (see Figures 2 and 3). Increasing by one unit of time led students to lose an average of 0.11 self-regulation points, or a loss of 0.08 standard deviation of self-regulation for a one standard deviation increase in time.

Model 1 shows that the share of within-student variance accounted for nearly half of the total variance in each variable: 42% of autonomous motivation in mathematics and 48.3% of academic self-regulation. For the same student, both motivation in mathematics and self-regulation varied significantly over time. The decline in motivation and self-regulation was greater for those who reported low levels of motivation and self-regulation at baseline [$\Delta_{deviance\_motivation}$(Model2-Model3) = 22.50, *ddl* = 1 *p* < .001, *r* = -.27; $\Delta_{deviance\_self\text{-}regulation}$(Model2-Model3) = 10.40, *ddl* = 1, *p* = .001, *r* = -.24].

This model also shows that the between-student variance accounted for a large portion of the total variance in the measures, 54.4% of the variance in autonomous motivation in mathematics and 50.3% of the variance in academic self-regulation. This large variability reveals that initial levels of autonomous motivation and self-regulation differed greatly among students within a school.

Between-school variance was also significant but very small; it accounted for 3.6% of the differences in mathematics autonomous motivation scores as well as 1.4% of the differences in self-regulation scores. The decline in motivation and self-regulation was greater in institutions with low initial levels of motivation and self-regulation [$\Delta_{deviance\_motivation}$(Model4-Model5) = 14.20, *ddl* = 1, *p* < .001, *r* = -.61; $\Delta_{deviance\_self\text{-}regulation}$(Model4-Model5) = 10.70, *ddl* = 1, *p* = .001, *r* = -.72].

Table 6

Effects of the Control Variables

Students' initial mathematics level and vocational track were introduced as control variables into the growth models and both proved significant effects (Table 8, Models 6). The higher the mathematics GPA reported by the students prior to the start of the experiment, the higher their self-reported motivation in math (β = .39) and self-regulation (β = .22). In addition, the students studying electricity reported more autonomous motivation in mathematics than students studying care sector services (β = .44) and business (β = .42). No significant difference was observed between care and business students. The students studying care sector services reported more self-regulation overall than those studying electricity (β = .17) and business (β = .23). No differences in self-regulation were observed between the electricity and business students.

Effects of Jigsaw Method on the Motivation and the Self-Regulation

Models 6 also included the learning conditions. They had no significant effect which indicates there is no overall difference in students' mathematics motivation and self-regulation between learning conditions (Table 7). However, to test whether there were differences in change in students' mathematics motivation and self-regulation over the studied period, Models 7 included interactions between the learning conditions and time (Table 7). The results show that the interactions did not improve the fit of the models both for motivation in mathematics [$\Delta_{deviance\_motivation}$(Model 6-Model 7) = 0.60, *ddl* = 2, *p* = .44] and for self-regulation [$\Delta_{deviance\_self\text{-}regulation}$(Model 6-Model 7) = 0.10, *ddl* = 2,*p* = .75]. The pattern of trajectories was similar for students in all conditions: student motivation and self-regulation decreased over time at the same rate. Thus, hypotheses 1a and 1b cannot be confirmed since the Jigsaw method did not impact the trajectories of autonomous motivation in mathematics or self-regulation compared to weakly structured cooperative learning and business-as-usual learning.

Table 7

Moderator Variables

Effects of Cooperative Attitudes

The inclusion of cooperative attitudes (Table 8, Model 8) and of the interaction between learning conditions and cooperative attitudes (Table 8, Model 9) did not lead to a better fit of the trajectory models [$\Delta_{deviance\_motivation}$(Model 8-Model 9) = 1.60, *ddl* = 2, *p* = .21; $\Delta_{deviance\_self\text{-}regulation}$(Model 8-Model 9) = 1.50, *ddl* = 2, *p* = .22]. Regardless of the level of cooperative attitudes reported by the students, the trajectories of autonomous motivation and self-regulation did not differ as they decreased at the same rate. Based on the trajectories of motivation and self-regulation results, hypothesis 2a was not supported: cooperative attitudes do not moderate the effect of the Jigsaw method on students' trajectories of motivation and self-regulation.

Table 8

Moderating Role of Initial Mathematics Level

Models 10 and 11 presented in Table 9 investigate whether there is a moderating role of initial mathematics level on motivation and self-regulation trajectories. First, Model 10 included an interaction between initial mathematics level and time. The effects proved significant: The gap in motivation observed between low-achieving and high-achieving students at the start of the study is significantly reduced over time, β = -0.10. Second, Model 11 introduced a three-way interaction between initial mathematics level, learning conditions, and time. The results show that the three-way interaction is significant. This means that the gap between the learning condition trajectories differed according to the initial mathematics level of the students. Although the interaction was shown to have a significant impact, its effects were weak ($\beta_{motivation} = 0.09$; $\beta_{self\text{-}regulation} = 0.10$). The results presented in Figures 2 and 3 reveal that, whatever the learning condition, students with a high initial mathematics level reported more motivation and self-regulation than the others. Students with an average initial mathematics level reported less motivation and self-regulation, but more than those with a low initial level. Regarding the impact of the learning conditions, the trajectories were not similar between conditions for the low-achieving students. The trajectories of low-achieving students who learned in the usual way evolved differently. Their autonomous motivation in mathematics and their self-regulation maintained over time and even increased slightly, unlike the other two learning conditions in which a decrease was observed. Conversely, students with a high or average initial mathematics level had similar trajectories across the three conditions. The learning conditions did not modify the evolution of motivation or self-regulation for these students. These results support our alternative hypothesis that the Jigsaw method does not benefit students most in need of progress and support who seem to benefit more from the business-as-usual learning condition (2c).

Table 9

Figures 2 and 3

Discussion

The goal of this study was to investigate the effect of the Jigsaw method on students' trajectories of motivation in mathematics and self-regulation, as well as whether cooperative attitudes and initial mathematics level could moderate these effects. The results do not confirm our hypotheses regarding the influence of the Jigsaw method on the evolution of students' motivation and self-regulation (Cerasoli et al., 2014; Dent & Koenka, 2016; Taylor et al., 2014). Regardless of the learning method (Jigsaw, weakly structured cooperation, or business-as-usual), we observed a similar decline in students' motivation and self-regulation trajectories over time. These declines are not abnormal in high school and align with trajectories typically observed (e.g., Caprara et al., 2008; Lepper et al., 2005). Our results are consistent with those of Roseth et al. (2019), which showed no impact of the Jigsaw method on changes in student motivation relative to business-as-usual learning. There are three possible explanations for our results. The first one is that the Jigsaw method may lead students to have individualistic or competitive attitudes rather than cooperative ones during the individual and expert group work stages (Roseth et al., 2019). Cooperative attitudes are only really useful during jigsaw group work. Given that students may adopt a variety of relational attitudes (i.e., individualistic, competitive, and cooperative) during the Jigsaw method, it is possible that the majority of students did not see the added value of working in structured cooperation in mathematics. This is corroborated by comments made by students during our initial visits to gain insight into how the Jigsaw method was being implemented in the classroom, for example "we don't understand why we are doing this". This supports the findings of Buchs et al. (2015) who showed the importance of preparing students for cooperation in order for it to be successful. The second explanation may be due to a perceived lack of autonomy in the Jigsaw method compared to weakly structured cooperative learning. Even though the Jigsaw method is supposed to make students more responsible, competent, and motivated for academic tasks, the lack of autonomy reported by the students may negate its positive effects. For instance, Hänze and Berger (2009) showed that in the context of the Jigsaw method, students reported a lower sense of learning autonomy than when working in a weakly structured cooperative context, which affected their intrinsic motivation. Finally, without verifying the accuracy of arguments from expert students during the puzzle group, some, particularly those who were highly persuasive, might have disseminated misinformation or delivered discourse that was ambiguous and lacking in structure (Slavin, 2014b). In this context, working with the jigsaw method is no more effective and motivating than an unstructured cooperative situation (Buchs et al., 2004; Buchs & Butera, 2009). For academic self-regulation, two hypotheses may explain the non-significant impact of the Jigsaw method compared to the other conditions in this study. The first one is that the Jigsaw method does not increase overall self-regulation abilities, but only certain self-regulation strategies. Moreno (2009) showed that during a learning sequence with the Jigsaw method, students mobilized more information retention strategies and fewer elaboration strategies than those in weakly structured cooperative learning. The second, less optimistic hypothesis is that in a jigsaw group, students may not monitor their own or others' understanding any more than in a weakly structured cooperative learning situation. According to Moreno's (2009) results, students in the Jigsaw method condition made fewer connections between learned concepts than in weakly structured cooperative learning.

We have also noticed differences in levels of motivation and self-regulation among students across vocational tracks. This can be primarily attributed to the fact that in the "electricity" track, almost all students are men, and they generally perceive themselves as more capable of excelling in mathematics than women (OECD, 2015). Additionally, students in the "care" track, predominantly women, are known to exert more effort in self-regulation and maintaining attention in class (Else-Quest et al., 2006). We believe, however, that the mechanisms observed in the implementation of the Jigsaw method would have been the same whatever the discipline in which the experiment was conducted: as Cochon Drouet et al. (2023) point out, it seems that the complexity of the material studied determines the benefits of the method, regardless of the subject.

Our final concern in this study was with factors that might moderate the effects of the Jigsaw method. Contrary to our expectations regarding students' cooperative attitudes, the Jigsaw method was not found to be more effective when students have high cooperative attitudes. Our results are at odds with those observed by Roseth et al. (2019) who showed that the Jigsaw method led to better performance than usual learning when students reported high cooperative attitudes. However, in contrast to the results of Roseth et al. (2019), vocational students in the Jigsaw method condition of our study reported fewer cooperative attitudes at the end of the experiment than those in the usual learning condition. Although Roseth et al.'s (2019) measure of cooperative attitudes was different from the one we used, it cannot be ruled out that cooperative attitudes could be perceived as less useful for group work among vocational high school students.

Students' initial mathematics level was the only moderating variable to play a role. Depending on the learning condition, we found that low-achieving students in mathematics differed in their trajectories of motivation and self-regulation. Among low-achieving students, those who worked with the Jigsaw method or in weakly structured cooperation had descending trajectories during the two school years, while those who worked in the usual way had rather stable trajectories. Thus, it appears that like cooperative work in general, the Jigsaw method did not benefit the students who need the most support in their learning. It seems that the business-as-usual learning condition is the most favorable for these students and could have a buffer effect in these difficult academic tasks. This is in line with Deiglmayr and Schalk (2015) who showed that the Jigsaw method was less beneficial for low-achieving students when positive resource interdependence was high. Having individual responsibility probably proved to present such a high level of difficulty that students with low levels of prior mathematics achievement were neither able to enjoy the mathematics task, nor develop appropriate self-regulatory strategies. In addition, being visible can be particularly threatening to these students (Le Hénaff et al., 2015). Although our results support this idea, we must keep in mind that the effects of the initial mathematics level on the evolution of students' motivation and self-regulation are low. These results bring into question the usual teaching strategies of French vocational high school teachers, in particular those they use for students with low academic levels. In the literature, we have little information about these teaching methods, but our results suggest that this is an avenue to be explored. Indeed, it is possible that vocational high school teachers are used to setting up classroom organizations that are particularly beneficial to the students who need the most support in order to progress. Thus, teachers probably felt more comfortable guiding students through the business-as-usual learning condition. Further analysis of the business-as-usual condition revealed that teachers usually mobilized several modes of organization to teach mathematics: in groups, individually and as a whole class. It remains to be seen whether this type of teaching is explicit enough, provides appropriate guidance and is suitable for students with lower levels of prior achievement. Future studies should focus on understanding the processes at work in the daily practices of vocational high school teachers.

All these results suggest that caution should be exercised when implementing the Jigsaw method, especially if it is to be used to reduce academic gaps between students. While the theoretical foundations described by Roseth et al. (2019) support effective resolution of socio-cognitive conflicts in the Jigsaw context, we show that if conflict resolution occurs, its dynamics might be more relational than epistemic. In both expert group work and Jigsaw group work settings, students are not required to regulate conflict as a group or to focus on resolving the encountered problem. Without the requirement to interact constructively with their peers, students may exchange and transfer knowledge while prioritizing compliance to reach the common goal, i.e., accept the answers of group members without critically examining them, which is not conducive to their learning (Buchs et al., 2008; Buchs & Butera, 2015).

Limitations and Perspectives

The first limitation concerns the measures selected to measure self-regulation, cooperation, and students' initial mathematics level. In this study, the chosen measure of self-regulation is general and not specific to mathematics, unlike the measure of autonomous motivation. While self-regulation represents a general skill related to academic success (Dent & Koenka, 2016), it is likely that students implement different self-regulatory strategies based on the importance they place on the disciplines. Future studies should ensure that the specificity or generality of measures is aligned with their purpose, as well as strive to include behavioral self-regulation clues rather than only self-reported ones (Dent & Koenka, 2016). Regarding cooperative skills, the introduction of a direct complementary measure would also have provided a better understanding of the extent to which students' cooperative abilities impact the effectiveness of the Jigsaw method. Rather than measuring self-reported cooperative attitudes, this would involve assessing students' cooperative skills through small group exercises, measuring, for example, students' group coordination skills or creativity. In addition, the drawback of our measure of initial mathematics level is that not all self-reported grade point averages are comparable across classes and schools. Considering standardized test scores at the end of middle school or the beginning of high school would be more appropriate. It is also important to note that our study does not allow us to draw conclusions about the impact of the Jigsaw method on student performance, which we were unable to measure satisfactorily enough to include in the analyses.

Several research perspectives can be envisaged nevertheless. While our results show no added value of the Jigsaw method in developing students' self-regulation, they provide no information about the role of this method in developing socially shared regulation skills, which are essential for group success (Hadwin et al., 2017). Recently, Cecchini et al. (2020) found that in a structured cooperative learning context, students more often reported regulating their learning in groups rather than individually. Conversely, socially shared regulation was used less by students in weakly structured cooperative learning. In a context of positive resource interdependence, socially shared regulation might be high because students need to monitor and evaluate each other's understandings, whereas in weakly structured cooperative learning, the regulation of group work can be more easily directed by a single group member (Hadwin et al., 2017). Measuring regulation at a group level should thus be a priority for future studies. Another avenue of research would be to investigate the benefits of explicit social skills teaching conducive to cooperative work before and during learning with the Jigsaw method (Buchs & Butera, 2015). Currently, few studies have examined whether explicitly teaching certain social behaviors improves student learning in a Jigsaw method setting. A study by Souvignier and Kronenberg (2007) did not yield any convincing results since the social skills training provided by the experimenters did not allow Jigsaw method students to perform better than teacher-guided or cooperative learning classrooms. Further work on this topic is needed in order to determine what could be explicitly taught in order to facilitate cooperation between students or whether other methods such as project-based learning (Chiang & Lee, 2016) are more effective in improving the motivation and self-regulation of vocational school students. To gain a deeper understanding of the extent to which students' motivation and self-regulation skills evolve in a cooperative situation, we also propose investigating the effects of the jigsaw method by examining student interactions. Moreno (2009) recommended assessing certain mediating factors, such as the quality of information exchanged within the jigsaw group. Moreover, the gender composition of groups likely serves as a moderating factor in the effects, as cooperatively structured groups comprising only women demonstrate greater creativity compared to mixed-gender or solely male groups (Peter et al., 2021). Future research should also be extended to non-vocational schools.

Conclusions

Despite the popularity of the Jigsaw method in psychoeducational circles, the results of the present study concur with those of Roseth et al. (2019) and of Stanczak et al. (2022), and call for caution regarding its use if the purpose is to increase student motivation and self-regulation, and reduce the gap between low and high-achieving students. No benefits of the Jigsaw method emerged; this null effect should not be overlooked given the duration and the sample size of this study. Although more research is needed to take into account students' actual performance on standardized tests, the limitations mentioned above should encourage teachers to keep in mind that the Jigsaw method must be accompanied by guided and structured instructions the importance of which has been repeatedly demonstrated (e.g., Dignath & Büttner, 2008; Dignath et al., 2008; Donker et al., 2014; Jansen et al., 2019; Kyriakides et al., 2013).

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Figure 1

Implementation of the three learning conditions

<table>
<tr><th></th><th>Jigsaw method</th><th>Weakly structured cooperative learning</th><th>Business-as-usual learning</th></tr>
<tr><td rowspan="2">Step 1: Preparation</td><td colspan="2">Students are assigned to groups of 3 to 4</td><td rowspan="2">The learning sequence is prepared as usual</td></tr>
<tr><td colspan="2">The teacher introduces the theme and key notions</td></tr>
<tr><td rowspan="4">Step 2: Work on the sequence</td><td>Each group member works individually on a learning resource</td><td rowspan="3">Students work in groups on all the learning resources given by the teacher</td><td rowspan="4">The class works as usual</td></tr>
<tr><td>Students who have worked on the same resource meet in new groups to share their knowledge of the resource (expert groups)</td></tr>
<tr><td>Students leave the expert group to return to their original group. Each group member shares their expert knowledge, and together, the group complete the assignment (One student = one complementary resource)</td></tr>
<tr><td colspan="2">The teacher asks each group to present their work to the class</td></tr>
<tr><td>Step 3: Individual evaluation</td><td colspan="3">Students do a short test to assess their knowledge of the sequence</td></tr>
</table>

Figure 2

Autonomous mathematics motivation according to initial mathematics level and learning condition

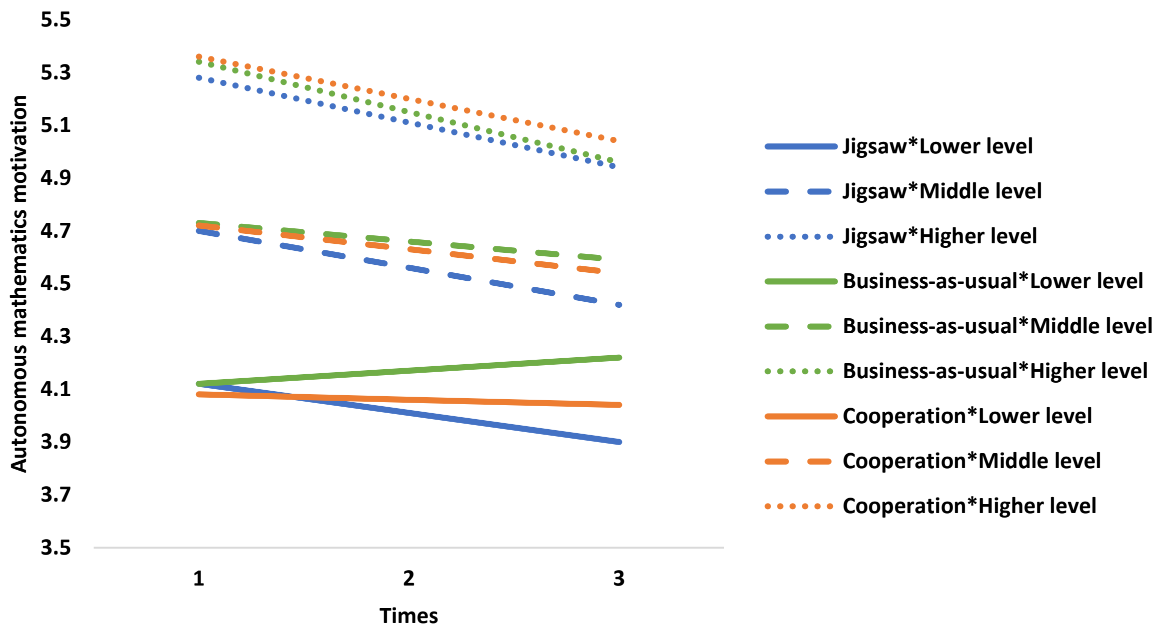

Figure 3

Academic self-regulation according to initial mathematics level and learning condition

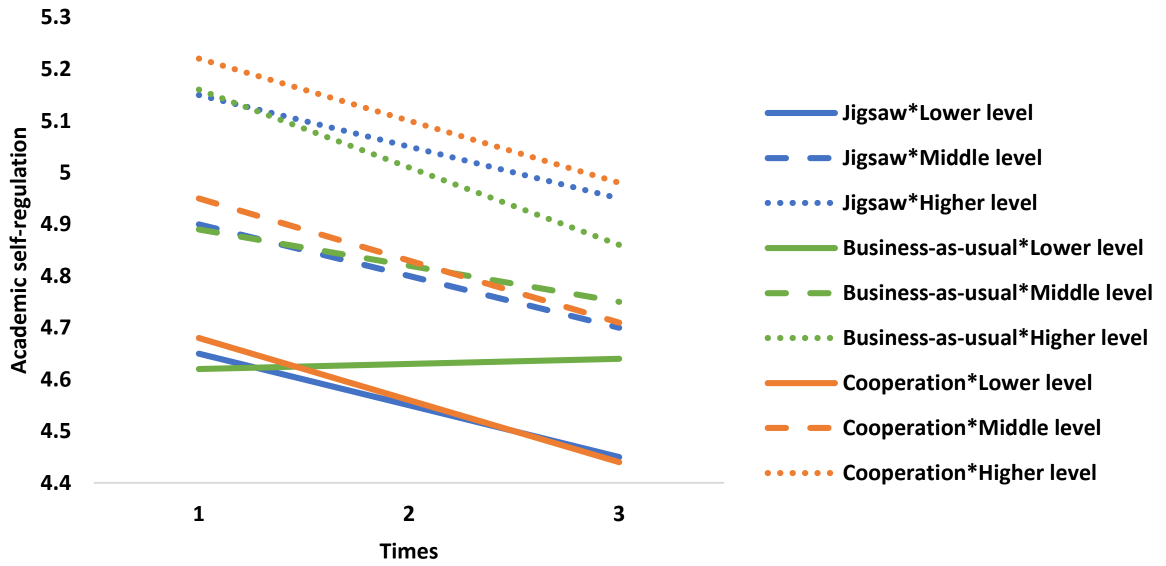

Table 1

Student assignment to learning conditions according to their vocational study subject

	Jigsaw method		Weakly structured cooperative learning		Business-as-usual learning		Total	
	N	%	*n*	%	*n*	%	*n*	%
Health services	552	10.56	628	12.02	587	11.23	1767	33.81
Business	715	13.68	691	13.22	791	15.13	2197	41.70
Electricity	526	10.07	449	8.60	289	5.53	1262	24.15
Total	1793	34.31	1768	33.83	1665	31.86	5226	

Table 2

Longitudinal invariance models of autonomous motivation in mathematics and academic self-regulation

	χ^2_{ML}	$\chi^2_{MLrobust}$	***df***	**CFI**	**RMSEA [IC < 0.90]**
Autonomous motivation					
Basic model	13881.1	10001.0	66		
Configural invariance	717.8	588.7	42	0.96	0.092 [0.086; 0.099]
Weak invariance	669.6	573.0	48	0.96	0.088 [0.082; 0.094]
Strong invariance	2085.3	1788.5	56	0.85	0.147 [0.142; 0.145]
Self-regulation					
Basic model	23163.3	16623.2	351		
Configural invariance	1617.6	1205.3	297	0.94	0.051 [0.049; 0.054]
Weak invariance	1638.9	1236.2	313	0.94	0.050 [0.048; 0.053]
Strong invariance	1798.3	1375.3	331	0.94	0.051 [0.049; 0.054]
Strict invariance	7186.4	5503.9	358	0.70	0.107 [0.104; 0.109]

Note. ML = maximum likelihood; CFI = comparative fit index; RMSEA = root-mean-square error of approximation; IC = confidence intervals

Table 3

Descriptive statistics by learning conditions

	Jigsaw method		Weakly structured cooperative learning		Business-as-usual learning		ANOVAs		
	M	*SD*	*M*	*SD*	*M*	*SD*	*F ratio*	*df*	*p*
Math level	2.26	1.09	2.11	1.09	2.37	1.11	21.53	1,4584	< .001
Cooperative attitudes									
Time 1	2.05	0.63	2.01	0.62	2.01	0.62	2.00	2,4279	*.14*
Time 2	1.90	0.63	1.89	0.60	1.95	0.57	2.61	2,3044	*.07*
Time 3	1.85	0.58	1.90	0.59	1.94	0.55	4.51	2,2152	.01
Autonomous motivation									
Time 1	4.44	1.54	4.34	1.61	4.43	1.58	1.70	2,4279	*.18*
Time 2	4.20	1.59	4.17	1.61	4.30	1.52	1.69	2,3044	*.18*
Time 3	4.25	1.60	4.19	1.53	4.27	1.62	0.45	2,2152	*.64*
Self-regulation									
Time 1	4.74	1.20	4.75	1.22	4.73	1.18	0. 05	2,4279	*.96*
Time 2	4.57	1.20	4.54	1.23	4.60	1.20	0.23	2,3097	*.66*
Time 3	4.67	1.24	4.63	1.20	4.62	1.22	0.32	2,2152	*.73*

Table 4

Correlation matrix at the three measurement times

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Autonomous motivation T1	-.-									
2. Autonomous motivation T2	.62**	-.-								
3. Autonomous motivation T3	.51**	.60**	-.-							
4. Self-regulation T1	.40**	.32**	.29**	-.-						
5. Self-regulation T2	.27**	.35**	.29**	.56**	-.-					
6. Self-regulation T3	.24**	.27**	.40**	.45**	.51**	-.-				
7. Cooperative attitudes T1	.01	.01	-.04	-.07**	-.09**	-.10**	-.-			
8. Cooperative attitudes T2	.02	.03	-.04	-.09**	-.09**	-.11**	.46**	-.-		
9. Cooperative attitudes T3	.02	.04	.03	-.05**	-.06**	-.09**	.38**	.47**	-.-	
10. Mathematics level	.44**	.36**	.33**	.25**	.19**	.20**	-.05**	-.04*	-.01	-.-

** p <.01; p < *.05

Table 5

Number of high schools by fidelity of implementation in cooperative learning

	Jigsaw classroom			Weakly structured cooperative learning		
	1st year *n*	2nd year *n*	Both years *n*	1st year *n*	2nd year *n*	Both years *n*
Good	11	17	9	6	7	7
Average	2	1	9	1	0	1
Poor	13	11	11	15	14	14
Unidentified	12	9	9	14	15	14

Table 6

Unconditional multilevel growth models of autonomous mathematics motivation and academic self-regulation

	Autonomous mathematics motivation					**Academic self-regulation**				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5
Fixed effects										
Intercept	4.39***	4.39***	4.39***	4.39***	4.39***	4.71***	4.71***	4.71***	4.71***	4.71***
Time	-0.12***	-0.12***	-0.12***	-0.12***	-0.12***	-0.11***	-0.11***	-0.11***	-0.11***	-0.11***
Random effects										
Between-school variance										
Intercepts	0.09	0.10	0.09	0.10	0.13	0.02	0.03	0.02	0.03	0.04
Slopes	--	--	--	0.02	0.02	--	--	--	0.005	0.01
Correlation Slopes/intercepts	--	--	--	--	-0.61	--	--	--	--	-0.72
Between-student variance										
Intercepts	1.36	1.35	1.52	1.51	1.50	0.74	0.74	0.81	0.81	0.81
Slopes	--	0.08	0.16	0.14	0.14	--	0.04	0.08	0.07	0.07
Correlation Slopes/intercepts	--	--	-0.27	-0.26	-0.25	--	--	-0.24	-0.24	-0.22
Within-student level 1	1.05	0.97	0.90	0.90	0.90	0.71	0.67	0.63	0.63	0.63
Deviance	33183.7	33158.4	33135.9	33117.2	33103.0	28751.4	28736.6	28726.2	28720.9	28710.2

***p < .001 ; **p < .01 ; *p < .05

Table 7

Multilevel growth models of the trajectories of autonomous mathematics motivation and academic self-regulation

	Autonomous mathematics motivation				Academic self-regulation			
	Model 6		Model 7		Model 6		Model 7	
	b	SE	b	SE	b	SE	b	SE
Fixed Effects								
Intercept	2.97***	0.07	2.97***	0.08	4.03***	0.06	4.03***	0.06
Time	-0.13***	0.02	-0.13**	0.04	-0.12***	0.02	-0.12***	0.02
Mathematics level	0.56***	0.02	0.56***	0.02	0.24***	0.01	0.24***	0.01
Vocational track (Business)								
Health services	0.02	0.05	0.02	0.05	0.23***	0.04	0.23***	0.04
Electricity	0.43***	0.06	0.43***	0.06	0.05	0.04	0.05	0.04
Condition (Business-as-usual)								
Jigsaw	0.03	0.07	0.04	0.09	0.06	0.05	0.05	0.06
Cooperation	0.05	0.07	0.03	0.09	0.06	0.05	0.07	0.06
Time*Business-as-usual								
Time*Jigsaw	--		-0.02	0.05	--		0.01	0.04
Time*Cooperation	--		0.02	0.05	--		-0.00	0.04
Random effects								
Between-school variance								
Intercepts	0.08		0.08		0.03		0.03	
Slopes	0.02		0.02		0.01		0.01	
Correlation Slopes/intercepts	-0.57		-0.57		-0.69		-0.69	
Between-student variance								
Intercepts	1.06		1.06		0.72		0.72	
Slopes	0.14		0.14		0.07		0.07	
Correlation Slopes/intercepts	-0.16		-0.16		-0.19		-0.19	
Within-student variance	0.90		0.90		0.63		0.63	

	Autonomous mathematics motivation		Academic self-regulation	
	Model 6	Model 7	Model 6	Model 7
Deviance	32108.4	32107.8	28374.0	28373.9

Note. Cooperation = Weakly structured cooperative learning condition

***p < .001 ; **p < .01 ; *p < .05

Table 8

Multilevel growth models of the trajectories of autonomous mathematics motivation and academic self-regulation with the learning conditions and cooperative attitudes

	Autonomous mathematics motivation				Academic self-regulation			
	Model 8		Model 9		Model 8		Model 9	
	b	SE	b	SE	b	SE	b	SE
Fixed effects								
Intercept	2.79***	0.08	2.81***	0.14	4.23***	0.06	4.27***	0.11
Time	-0.12***	0.02	-0.08***	0.10	-0.12***	0.02	-0.14	0.08
Mathematics level	0.56***	0.02	0.56***	0.02	0.24***	0.01	0.24***	0.01
Vocational track (Business)								
Heatlh services	0.02	0.05	0.01	0.05	0.22***	0.04	0.22***	0.04
Electricity	0.42***	0.06	0.42***	0.06	0.05	0.04	0.05	0.04
Implementation good/average	0.18*	0.07	0.21**	0.08	0.12*	0.06	0.12*	0.06
Cooperative attitudes	0.08***	0.02	0.08	0.06	-0.09***	0.02	-0.12*	0.05
Condition (Business-as-usual)								
Jigsaw	--		-0.10	0.17	--		-0.07	0.14
Cooperation	--		-0.03	0.17	--		-0.18	0.14
Condition*cooperative attitudes (Business-as-usual)								
*Jigsaw*attitudes*	--		0.02	0.07	--		0.04	0.06
*Cooperation*attitudes*	--		0.01	0.08	--		0.11	0.06
Time* cooperative attitudes	--		-0.02	0.05	--		0.01	0.04
Time*Condition (Business-as-usual)								
*Time*Jigsaw*	--		-0.10	0.14	--		0.12	0.11
*Time*cooperation*	--		0.08	0.14	--		0.10	0.11
Time*Condition*Attitudes (Business-as-usual)								
*Time*Jigsaw*attitudes*	--		0.05	0.07	--		-0.06	0.05
*Time*cooperation*attitudes*	--		-0.03	0.07	--		-0.05	0.05
Random effects								
Between-school variance								
Intercepts	0.07		0.07		0.03		0.03	
Slopes	0.02		0.02		0.01		0.01	
Correlation slopes/intercepts	-0.55		-0.56		-0.70		-0.68	
Between-individual variance								
Intercepts	1.05		1.05		0.71		0.71	
Slopes	0.13		0.13		0.07		0.07	
Correlation slopes/intercepts	-0.16		-0.16		-0.19		-0.20	
Within-individual variance	0.90		0.90		0.63		0.63	
Deviance	32090.8		32085.7		28351.7		28343.8	

***p < .001 ; **p < .01 ; *p < .05

Table 9

Multilevel growth models of the trajectories of autonomous mathematics motivation and academic self-regulation with the learning conditions and mathematics level

	Autonomous mathematics motivation				**Academic self-regulation**			
	Model 10		Model 11		Model 10		Model 11	
	b	SE	b	SE	b	SE	b	SE
Fixed effects								
Intercept	2.95***	0.10	2.87***	0.11	4.07***	0.08	3.98***	0.08
Time	0.04	0.04	0.17	0.07	-0.06	0.03	-0.09	0.06
Vocational track (Business)								
Health services	0.02	0.05	0.02	0.05	0.22***	0.04	0.22***	0.04
Electricity	0.42***	0.06	0.41***	0.06	0.04	0.04	0.04	0.04
Implementation good/average	0.21**	0.08	0.21**	0.08	0.11*	0.06	0.11*	0.06
Mathematics level	0.58***	0.03	0.61***	0.04	0.23***	0.03	0.27***	0.03
Condition (Business-as-usual)								
Jigsaw	-0.12	0.13	0.03	0.14	-0.07	0.10	0.05	0.11
Cooperation	-0.14	0.12	-0.17	0.14	-0.08	0.10	0.06	0.11
Condition*mathematics level (Business-as-usual)								
*Jigsaw*mathematics level*	0.02	0.04	-0.03	0.05	0.03	0.04	-0.02	0.04
*Cooperation*mathematics level*	0.06	0.04	0.03	0.05	0.05	0.04	0.00	0.04
Time* mathematics level	-0.07***	0.01	-0.12***	0.03	-0.03*	0.01	-0.08***	0.02
Time*Condition (Business-as-usual)								
*Time*Jigsaw*	--		-0.25*	0.10	--		-0.19*	0.08
*Time*Cooperation*	--		-0.12	0.10	--		-0.21**	0.08
Time*Condition*Math level (Business-as-usual)								
*Time*Jigsaw*mathematics level*	--		0.09**	0.04	--		0.08**	0.03
*Time*cooperation*mathematics level*	--		0.05	0.03	--		0.08**	0.03
Random effects								
Between-school variance								
Intercepts	0.07		0.07		0.03		0.03	
Slopes	0.02		0.02		0.01		0.01	
Correlation slopes/Intercepts	-0.58		-0.59		-0.70		-0.69	
Between-student variance								
Intercepts	1.05		1.05		0.72		0.71	
Slopes	0.13		0.13		0.07		0.07	
Correlation slopes/Intercepts	-0.16		-0.15		-0.19		-0.19	
Within-student variance	0.90		0.90		0.63		0.63	
Deviance	32072.6		32065.3		28362.5		28350.9	

***p < .001 ; **p < .01 ; *p < .05