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ABSTRACT

During the first lockdown due to Covid-19 pandemic, project-based learning (PBL) had to be implemented remotely. To gain knowledge on this learning context, we monitored motivation (in Self-Determination Theory framework), flow, social identification and self-rated performance during a 10-day project conducted with 281 engineering students. Final grades were also collected as objective performance indicators. Results show that intrinsic and identified motivation, flow, self-rated performance and group identification increased throughout the project, which suggests that remote PBL stimulated students' needs for autonomy and competence without hindering their need for relatedness. Furthermore, the analysis of significant predictors of teams' and individuals' performance draw avenues for improving PBL and stimulating intrinsic and identified motivation, for the subject and for the project, at the right time along the program.

Keywords: emote project-based learning (PBL), motivation, flow, social identification, engineering students

Introduction

"PBL is an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem. Critical to the success of the approach is the selection of ill-structured problems (often interdisciplinary) and a tutor who guides the learning process and conducts a thorough debriefing at the conclusion of the learning experience." (Savery, 2006, p. 12). Project-based learning (PBL) is becoming common in Engineering Education for two main reasons. First, industry is more and more demanding of non-technical skills and the professional world is not satisfied with the results of traditional academic curricula on graduates' capabilities. Second, the shift in accreditation procedures in Engineering towards outcome-based accreditation is also a driver in many countries (Beddoes, Jesiek & Borrego, 2010). Thanks to the PBL approach, students develop their thinking skills, creativity, and capacity to cooperate (Chiang & Lee, 2016). PBL is said to be more challenging and engaging for students than standard teaching because they have to solve real-life problems (Solomon, 2003). It is also recognized that PBL pedagogy is more motivating for pupils than classical pedagogies. However, keeping students motivated is challenging whatever the pedagogical method, and motivation seems to be a critical factor in learning (Lim, 2004).

Motivation is a complex part of human psychology (Bakar, 2014) and can be defined as "what causes people to behave as they do" (Denhardt et al., 2008, p. 146). In other words, being motivated means being moved to do something (Ryan & Deci, 2000a). Motivation explains students' choices of learning tasks, time and effort invested, persistence, and resistance to the difficulties encountered (Bakar, 2014). Among the numerous models of motivational processes, Self-Determination Theory (STD) (Deci & Ryan, 1985) appears to currently be the most researched and applied in the field of psychology (Ryan et al., 2019). Also, this theory is often used to explain students' motivations to learn (Hartmann & Gommer, 2019; Reeve, 2012) and to study motivation in PBL approaches (for example see Wijnia & Servant-Miklos, 2019). Based on SDT, people are motivated by three universal psychological basic needs: autonomy (feeling self-governed and self-endorsed), relatedness (feeling interacted) and competence (feeling competent) (Deci & Ryan, 2000a; Ryan & Deci, 2000b). These needs initiate or regulate human behavior (Guay et al., 2000). Reeve (2013) demonstrated that when classrooms support these three needs, students are more engaged in learning. Deci and Ryan (1985) established a continuum of self-determination on which they distinguished six types of motivation ranging from amotivation to intrinsic motivation with various levels of extrinsic motivation in between (external regulation, introjected regulation, identified regulation, integrated regulation) which result from the process of internalization. Deci and Ryan (2000) define intrinsic motivation "as the doing of an activity for its inherent satisfaction rather than for some separable consequence" whereas "extrinsic motivation is a construct that pertains whenever an activity is done in order to attain some separable outcome". In introjected regulation, individuals seek to achieve internal positive consequences (e.g., pride, self-esteem). Identified regulation introduces values: individuals identify with the perceived value of a behavior. The higher the identification with target values, the higher the commitment and performance (Deci & Ryan, 2000), like someone practicing sport not for intrinsic immediate pleasure but for health purposes. Finally, integrated regulation results in an even higher identification integrating with deeper aspects of the self (Deci & Ryan, 2000). Research has demonstrated that intrinsic motivation and curiosity-driven education are fundamental for efficient education (Freeman et al., 2014, as cited in Oudeyer et al., 2016) and for more effective learning (Baranek, 1996). Moreover, when individuals are intrinsically motivated, they are more creative (Amabile, 1983; Amabile et al., 1986; Reeve & Deci, 1996). PBL allows students to take greater responsibility for their own learning and previous research has suggested that PBL might have a positive effect on student motivation (Blumenfeld et al., 1991; Weiss, 2016). This assumption is due to the fact that students are autonomous to drive their collaborative process to investigate the constitutive problem of the PBL framework and that this requires students' effort over an extended period (Blumenfeld et al., 1991). This mechanism is likely to increase student intrinsic motivation (Douglass & Morris, 2014).

Beyond this inherent potential of PBL, other parameters influencing students' motivation related to PBL have to be considered. For example, Dolmans and Schmidt (2006) pointed out that group discussions positively influence students' intrinsic interest in the subject matter under discussion. The recent research of Yilmaz et al. (2020) connected the effects of the e-leadership approaches among the group with motivation. The authors compared the benefit of the vertical and shared e-leadership approaches in online PBL on self-regulated learning skills, motivation and group collaboration processes. The authors mention that both leadership approaches were found useful in the management of groups with some advantages and disadvantages in both approaches. Indeed, the e-shared leadership allows the fostering of the sense of belonging to the group ensuring a fair distribution of responsibility among the teammates. The vertical e-leadership approach bears the advantage of enhancing the communication, cooperation and coordination among group members (Yilmaz et al., 2020). Concerning motivation, they found that both e-leadership approaches are effective in increasing students' motivation before and at the end of the project. Considering the role of the tutor, Harun et al. (2012) demonstrated that through systematic motivation given by the tutor, the level of student's motivation can be increased. It has to be mentioned that the study of Harun was undertaken under the particular context of the transition from a conventional teaching method to PBL. Thus, as the authors mention, students were non-familiar with PBL with a negative mindset at the start of the project. In the case of the transition from a conventional teaching method to PBL, the key role of tutor was also mentioned by Fukuzawa et al. (2017) who observed a decrease of motivation among students. The authors pointed out that motivation was higher in students with more subject experience at the beginning of the course but decreased during the course in relation to subject matter experience. To explain this phenomenon, the authors emphasized the role of the tutor to ensure a good implementation of PBL in a traditional curriculum: in PBL, the teacher has to act as a tutor and to become a facilitator for the learners (Hmelo-Silver, 2004).

The extreme experience of intrinsically motivating human activities (autotelic experience) is called the flow. It corresponds to the experience during which individuals are fully involved in the present moment (Nakamura & Csikszentmihalyi, 2002), a state of optimal experience and maximal concentration, when people act at the peak of their capacity (Csikszentmihalyi, 2008; Csikszentmihalyi & LeFevre, 1989; Šimleša et al., 2018). The literature suggests that there is a positive relationship between flow and performance in learning settings (Engeser et al., 2005; Schüler, 2007, as cited in Schüler & Brunner, 2009), artistic and scientific creativity (Perry, 1999; Sawyer, 1992, as cited in Schüler & Brunner, 2009), and that flow can predict academic performance (Engeser & Rheinberg, 2008). Flow may also be positively related to creativity (MacDonald et al., 2006; Zubair & Kamal, 2015; Cseh et al., 2015). Specific scales were also developed to measure flow in educational settings (Heutte, 2011; Heutte et al., 2016). Although conceptualized as an individual experience, flow was also studied in the social context of interindividual collaboration such as small groups (Salanova et al., 2014), music ensembles (Sawyer 2003, 2006), dyads (Walker, 2010) and working teams in organizations (Van den Hout, 2016). Research showed that cognitively absorbed teams (which is a dimension of flow) demonstrate higher levels of performance (Rutkowski et al., 2007). Limited, but growing research on collective flow (Šimleša, 2018) finds that the flow in interdependent collaborative social interactions is stronger and more enjoyable than solitary flow experience (Walker, 2010). The notion of collective flow is closely linked to the social dimension of teamwork and social identification. Social Identity Theory (Tajfel et al., 1979) posits that identity varies along a continuum referring to interpersonal behavior on one side ("I" vs. "you"; personal identity) and intergroup behavior on the other ("us" vs. "them"; social identity). Social identification, or sense of belonging, relies on common features that are shared by the group members and distinguish them from relevant other groups. This theory applies to individual productivity within teams (Worchel et al., 1998). Group productivity is enhanced by factors that increase group categorization (group name or lab coat) and the importance of the group to members' social identities (Worchel et al., 1998). If group members are more identified to their team, this social mechanism may enable better cooperation both in terms of subjective experience (flow, motivation) and objective output (performance to the task at hand). Positive affective experience of teamwork is found to be significantly associated to team creativity (Shin, 2014).

If we take the 4 principles of PBL pedagogy proposed by Dolmans and colleagues (2005; 2019), namely: contextual learning (learning based on professional relevant context), constructive learning (active process with construct and reconstruct knowledge), self-directed learning (students determine their own learning needs) and collaborative learning (collaboration between learners) to enhance learning, we observe that they may all contribute to creating a favorable ground for the expression of intrinsic motivation. Hence PBL seems likely to satisfy the needs for competence, autonomy and relatedness.

All the results presented above come from studies on face-to-face PBL, but are they still valid when PBL goes online? Regarding online PBL, the scientific literature appeared at the very end of the 20th century, when e-learning burst out, mainly in the form of papers about experiments of dedicated environments inspired by the works of the Computer-Supported Collaborative Learning (CSCL) community (Malopinsky et al., 2000; Orrill, 2002; Chernobilsky et al., 2005). A few years later two handbooks appeared that lay the foundations of Online PBL, supported by text-based collaborative environments (Savin-Baden & Wilkie, 2006; Savin-Baden, 2007).

New synchronous collaborative technologies, such as computer videoconferencing, are progressively integrated in Online PBL research, with the development of PBL online courses using Adobe Connect (Ng et al., 2014; Lajoie et al., 2014), immersive platforms (Liu et al., 2014), Google Hangouts (Hazwanie et al., 2017). Other experiments used various combinations of tools to support the PBL courses with different functionalities such as collaboration, discussion, storage, etc. (Van Oostveen et al., 2014; Virtanen & Rasi, 2017; Havenga, 2000). Such combinations of tools became a common configuration used by online PBL during the second part of the last decade, and turned out to be the most common during and after the Covid-19 lockdowns. The latest guidelines and handbooks account for this fact (Ozogul, 2018; Savin-Baden & Bhakta, 2019; Budhai & Skipwith, 2022). A new type of research appeared and developed with the generalization of online PBL: comparative research trying to measure the differences in various achievements of online PBL versus those of traditional PBL. Some pieces of this comparative research are real meta-analyses (Jurewitsch, 2012; Tudor Car et al., 2019), but the bulk of these works, since the Covid-19 pandemics, compared various aspects of an online PBL course with the same aspects in the same course delivered face-to-face (Elzainy et al., 2020; Caroni & Nikoulina 2021; Beneroso & Robinson, 2022).

The scientific interest in studies on motivation online emerged around 2010 and showed a considerable boost since the Covid-19 crisis (Mese & Sevilen, 2021). As with face-to-face studies, the theory of self-determination has demonstrated its effectiveness in studying online motivation (Hartnett, 2011). Our study is in line with this and has two original aspects. On the one hand, the study of students' motivation in an online PBL project including measures of students' flow and social identification – these three socio-cognitive variables being fundamentally linked. On the other hand, the variation over time of these three variables, which are usually measured once, at a given time and not repeated.

Research Setting

The present study was conducted in CESI[1] Graduate School of Engineering, a French educational institution created 60 years ago. As a CDIO Member[2], and because the professional life of an engineer is not a succession of lectures, exercise sessions and practical work, CESI Graduate School of Engineering has chosen to use active learning by Problem-and-Project-based-Learning from the first year of the undergraduate course up to the final year (Allard, 2018; Saveuse et al., 2017). CESI uses two different forms of Problem and Project-Based Learning that are briefly described below: APP and A2P2[3]. APP is the traditional form of Problem-Based Learning, as originally defined by Barrows (Barrows & Tamblyn, 1980). It has 3 phases (Raucent & Milgrom, 2010). It is generally used to address mono-disciplinary questions. In CESI, two APP cycles are achieved in a week, in alternation with other activities (language courses, workshops…). CESI and its partners Université de Louvain (Belgium) and Université du Québec à Montréal (Canada) have constructed A2P2 (Milgrom et al., 2015). It is used to achieve multi-disciplinary projects, lasting between 1 and 5 weeks. Each project is divided into cycles (1 per week), based on the 4 phases of the Deming Wheel (Plan, Do, Study / Check, Act). At the end of each cycle, a deliverable is expected. As for APP, the PDCA cycles of A2P2 are achieved in a week, in alternation with the same other activities.

1 CESI is a brand name, not an acronym. See http://cesi.fr/

2 CDIO is an international association of Schools delivering innovative Engineering Education, founded by the Massachusetts Institute of Technology (MIT). See http://www.cdio.org/

3APP is the acronym of "Apprentissage Par Problèmes" (Problem-Based Learning) and A2P2 the acronym of "Apprentissage Actif Par Projet" (Project-Based Active Learning). Both are described in detail in French in (Blandin, 2020), and in short, in English, in this paper.

To implement the PBL pedagogies, classrooms on the campuses are organized as multimedia meeting rooms equipped with several tables / desks for six students, according to the SCALE-UP model (Beichner & Saul, 2003). Students learn and work in teams, using the interactive digital environments to access the learning resources stored on a Moodle platform, hosted by a national private cloud system, which also allows storing their project's intermediate and final deliverables. For achieving collaborative teamwork during work periods in autonomy, students generally use communication tools belonging to their Personal Learning Environments (Dabbagh & Kitsantas, 2012), that can be defined as "a material, technical, human environment, built or shaped by a subject with a view to using it as a system of instruments for learning, and of which he has total freedom of use" (Blandin, 2016). Our students' Personal Learning Environments include applications such as Messenger, WhatsApp, Discord… coupled with tools for sharing documents such as Dropbox or Google Drive. The curriculum of each track is synchronous across all the campuses delivering the major in France. A tutor supervises and supports several teams of students in the same location. His/her main role is to monitor the progress of the project and to facilitate self-learning activities and prototype design and making, rather than to teach (Milgrom et al., 2022). All tutors in CESI are members of online communities managed at the national level, to which they contribute at least once a week. So, they are used to collaborating in remote settings.

During the Covid-19 pandemics, all educational institutions in France had to close their premises, and to provide distance-learning activities. During the lockdown, both APP and A2P2 pedagogies appeared to withstand the shift to distance learning. To ensure educational continuity in CESI, the organization of the multimedia meeting rooms has been virtually replicated as MS-Teams® channels by each tutor, and the students' teams continued their learning activities by meeting online, accessing as usual to their resources on Moodle, and using their usual collaborative tools. The APP and A2P2 steps, already scheduled, were the same. The only change was that videoconferencing sessions through MS-Teams® replaced the planned face-to-face meetings between students or between teams of students and their tutor. To our surprise, no other change appeared to be needed (Blandin, 2020). The main issue related to conducting PBL remotely was to ensure that distance teamwork would not decrease students' motivation, flow and social identification. We were concerned with a potential motivational collapse due to social isolation of each team member in the long run.

This study was carried out in this distance-learning configuration during the first lockdown in France (2020, mid-March to mid-May), and our goal was to measure the impact of such configuration on students' motivation, flow, social identification and performance during PBL. This unusual context led us to the following questions: How does online PBL impact students' motivation, flow, and social identification over time? How do these sociocognitive processes impact teams' performance?

At this stage, from the theories presented above, we can consider two hypothetical avenues:

Positive hypothesis (H1) – Increase over time: regarding motivation, we can assume that remote PBL may meet autonomy and competence needs. Conducting the project remotely may indeed foster self-discipline and can be perceived as more challenging for students. Regarding flow, one can assume that individual flow may increase because of students being alone at home, in their "cocoon" where they may be more able to concentrate. From this viewpoint, we may hypothesize that motivation, flow and self-rated performance will increase over the duration of the project and predict teams' final grade.

Negative hypothesis (H2) – Decrease over time: regarding motivation, we can assume that switching from face-to-face to online modality will be detrimental to meeting students' need for relatedness. Although PBL is likely to foster the social dimension of learning, implementing it remotely with each teammate in social isolation may hinder this known advantage. Accordingly, social identification of each student to his/her team as well as collective flow may be impaired due to distance between team members. In line with this reasoning, we may hypothesize that motivation, flow, social identification and self-rated performance will decrease over the duration of the project and predict teams' final grade.

This research is exploratory by nature, in particular for the following reasons: such situation of remote collaboration during PBL, with each team member under lockdown, is unprecedented. We failed to find previous literature regarding the time course of motivation, flow and/or social identification during a project. For these reasons, our position for the present study, between hypotheses H1 and H2, was open.

Methods

Participants

281 industrial engineering graduate course second year (4th year of studies) students (46 women, 234 men, Mean Age = 23, SD = 2.2) participated in this study. They were students from four campuses of CESI Graduate School of Engineering. They were distributed into 48 teams of 5 to 7 members from the same campus. Teams were formed before the start of the project. There was one corresponding tutor for 5 teams from the same campus.

Material

We used MS-Teams® and each campus created one "plenary room" to circulate the questionnaires, and a series of rooms for students' teams, to be used for workshops and sessions in autonomy. As usual, Moodle was used for delivering and gathering all project resources (presentations, instructions, exercises…) as well as complementary resources (videos, articles…) and students' production.

To assess sociocognitive variables (motivation, flow, social identification and self-rated performance) and monitor their evolution throughout the project, students were invited to complete individually an online questionnaire via Google Forms. The link to the questionnaire was sent in the morning after the call on the MS-Teams® "plenary room". One teacher per campus was responsible for posting the link on the conversation. Students had between 10 and 15 minutes to complete the questionnaire.

The online questionnaire was designed as follows, with all items to be answered on a 7-point Likert-type scale (1 = strongly disagree; 7 = strongly agree). Students completed the online questionnaire 3 times: at the beginning, (on Day 1, which corresponds to Time 1 or T1), middle (on Day 5, which is Time 2 or T2) and end of the project (on Day 9, which is Time 3 or T3).

For the first completion (T1), the questionnaire was based on the Situational Motivation Scale (Guay, Vallerand, & Blanchard, 2000). It measured Intrinsic motivation for the project at the beginning (α = 0.903, e.g., "I am engaging in this project because I find it interesting"), Identified motivation (α = 0.815, e.g., "…because I chose to do it for my own good"), External regulation (α = 0.747, e.g., "…because I am supposed to do it"), and Amotivation (α = 0.831, e.g., "There might be good reasons to do it, but personally, I don't see any"). For the second and the third completion (T2 and T3), the questionnaire included the Situational Motivation Scale as in T1 and we added other scales: the Flow Short Scale (Rheinberg et al., 2002) restricted to 2 dimensions: Absorption (α = 0.760, e.g., "I felt just the right amount of challenge") and Fluency (α = 0.869, e.g., "My thoughts ran fluidly and smoothly"), which were aggregated as a single Flow dimension (α = 0.845); the Single-item Social Identification Scale (Postmes et al., 2013) measuring group identification ("I strongly identified with my group") and a Self-rated performance, which was assessed through 6 customized items: 3 addressing individual performance ("I had a lot of ideas", "I had high quality ideas", "I showed high performance") and 3 dedicated to collective performance ("My team had a lot of ideas", "My team had high quality ideas", "My team showed high performance"). They were aggregated into a single Self-rated performance score (α = 0.873).

Team performance score (on an 80-point scale) was collected as the sum of grades awarded to the project defenses (each rated 1 = poor to 5 = outstanding). The assessment grid was based on 16 criteria, some of which were related to the content of the project deliverables, other ones being related for example to balance between team members' contributions, to the quality of the defense or the quality of the prototype produced.

Individual performance was recorded as the number of correct answers to a proficiency test: five months after the end of the project, students had to individually complete a Multiple-Choice questionnaire in order to assess learning outcomes of this project. The questionnaire included 40 questions addressing general concepts related to the main topic of the project (definitions of innovation, strategies, and methods). We chose to wait 5 months to pass the proficiency test in order to determine the impact of motivation on the knowledge stored in long-term memory following the project.

Procedure

Data were collected during a 10-day project dedicated to learning Innovation (see Appendix 1). The objectives of this project were threefold: 1) to discover and understand what innovation is, 2) to acquire a global vision of the stages of an innovative product development process and 3) to approach innovation from the needs of the market. This project was designed in the abovementioned A2P2 framework, but with a more agile and iterative workplan (e.g., shorter cycles), consistent to how innovation is usually approached in startups and companies. We made sure to respect fundamental criteria of a PBL pedagogy like those proposed by Stoller (2006, as cited in Du & Han, 2016), which are as follows. 1) having a process and product (in this project, the goal was to develop an innovative product); 2) giving students ownership of the project (teams chose their own issue to address and the product to develop); 3) extending over a period of time (here: 10 days); 4) integrating skills (this project focused particularly on creativity, technological and competitive watch and business model creation); 5) developing students' understanding of a topic through the integration of language and content; 6) collaborating with other students and working on their own; 7) holding students responsible for their own learning through the gathering, processing, and reporting of information from target language resources; 8) assigning new roles and responsibilities to students and teacher; 9) providing a tangible final product (here: a material or digital prototype); 10) reflecting on both the process and the product. We used two phases during the innovation project in line with some PBL approaches (Drain, 2010; Good & Jarvenin, 2007, as cited in Kokotsaki et al., 2016):

1) "To seek" Phase (day 1 to day 3) – knowledge and skills acquisition

In this phase, a fictitious concept was proposed to enable students to identify and understand the expected steps of the project, namely: innovation definition, technology and methodology watch, benchmarking, use analysis, creativity, prototyping and business model. Knowledge acquisition was supported by: **One-hour conferences** led by an expert on a key concept. This project counted 7 conferences: innovation, use analysis, ethics, creativity, business model, watch and biomimicry; **Workshops** supervised by tutors, in which teams had to put into practice the topics covered in conferences; **Intermediate deliverables** sent by teams to their referring tutor after workshops. There were 3 intermediate deliverables: innovation mind map, empathy map + idea sheet, and business model.

2) "To play" Phase (day 4 to day 10) – knowledge and skills application

During this phase, teams worked in autonomy on their own project. Each team was expected to identify some unmet need, to follow a structured approach and to implement an innovative concept. Teams could start from their own idea of an unmet need, or engage in a challenge proposed by an open innovation platform:

- Challenge 1: how digital technologies can be used in healthcare to improve people's lives?
- Challenge 2: design a low-cost, simple, easy-to-use and easy-to-build ventilator for Covid patients in an emergency timeframe;
- Challenge 3: imagine a neighborhood to achieve socially sustainable development for all.

Working in autonomy means that each team's referring tutor was available to answer questions. Tutors would also go from team to team on a regular basis to ensure that everything was fine. At the mid-point of this phase, a mentoring session was organized. Teams presented their project to experts who asked them questions and gave some advice.

There were 4 final deliverables: 1) project management plan, 2) results of technology watch, 3) idea sheet and use analysis and 4) a "Soleau envelope"[4] describing the final concept. The last day, teams presented their projects during two final defenses: 1) a collective defense in English dedicated

4 A document used to certify the date of creation of an idea or of an invention when registered by INPI (French National Institute for Industrial Property)

to the business model (10 min presentation + 15 min questions); 2) a general collective defense in French covering the process followed, methods used and prospects in front of a jury of experts (10 min presentation + 15 min questions).

The procedure and instructions were identical for all campuses. Students were engaged full-time (from 8:30 to 12:30 and from 13:30 to 17:30) for 10 days distributed in two consecutive weeks. Appendix 1 summarizes the planning of the project including the two phases, the organization of each day, deadlines of deliverables and filling out questionnaires (in red).

Results

We first analyzed the time course of individual processes (motivation, flow, social identification and self-rated performance) throughout the project, using repeated-measurement analyses of variance. We then ran two multiple linear regressions in order to find predictors of the final group performance and the individual performance (learning outcomes five months afterwards). All analyses were performed with SPSS 21.

Time Course of Individual Processes

Intrinsic motivation showed continuous increase during the project ($F(2,162) = 20.56$, $p < 0.001$). Fisher's LSD pairwise comparisons confirm a significant increase from T1 (M = 4.74, SD = 1.05) to T2 (M = 5.21, SD = 0.126, p = 0.002) and from T2 to T3 (M = 5.634, SD = 0.118, p = 0.002). Identified motivation also significantly increased ($F(2,162) = 5.575$, $p = 0.005$). Pairwise comparisons showed no difference between T1 (M = 4.83, SD = 1.11) and T2 (M = 4.80, SD = 1.33, p = 0.842) but a significant increase between T2 and T3 (M = 5.21, SD = 1.39, p = 0.001). External regulators did not significantly vary throughout the project ($F(2,162) = 0.524$, $p = 0.593$), with a similar amount of extrinsic motivation between T1 (M = 4.53, SD = 1.51), T2 (M = 4.69, SD = 1.45) and T3 (M = 4.58, SD = 1.58). Amotivation did not vary either ($F(2,162) = 1.523$, $p = 0.221$) between T1 (M = 2.77, SD = 1.42), T2 (M = 2.51, SD = 1.26) and T3 (M = 2.62, SD = 1.35). Flow, which was collected only at T2 (M = 4.85, SD = 1.02) and T3 (M = 5.33, SD = 0.89), proved to significantly increase between the two measurements ($F(1,87) = 22.508$, $p < 0.001$). Group identification also significantly increased between T2 (M = 5.59, SD = 1.32) and T3 (M = 5.91, SD = 1.06), $F(1,87) = 6.508$, $p = 0.012$). Finally, self-rated performance showed similar increase between T2 (M = 5.17, SD = 0.10) and T3 (M = 5.59, SD = 0.09, $F(1,87) = 15.305$, $p < 0.001$). All these results are summarized in Figure 1.

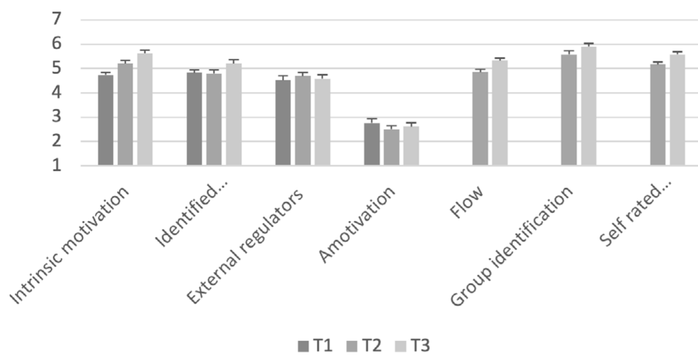

Figure 1. Significant results of time course on individual processes collected at T1, T2 and T3. Regression Model to Predict Team Performance

All previous variables were included in a regression model with Team performance as dependent variable. Detailed results are presented in Table 1.

The results emphasize two significant negative predictors (Flow and Identified motivation at T2) and three significant positive predictors (Self-rated performance at T2, Intrinsic motivation at T2 and Identified motivation at T3).

Regression Model to Predict Individual Performance

The same predictors were included in a regression model with Individual performance as dependent variable. Detailed results are presented in Table 2.

Predictors	Standardized coefficient	t	p
T1-Intrinsic motivation	-0.100	-0.697	0.489
T1-Identified motivation	-0.125	-0.769	0.445
T1-External regulator	0.232	1.673	0.099
T1-Amotivation	-0.196	-1.183	0.241
T2-Social identification	0.091	0.582	0.563
T2-Flow	*-0.554*	*-2.942*	*0.005*
T2-Self-rated performance	**0.551**	**3.221**	**0.002**
T2-Intrinsic motivation	**0.491**	**2.309**	**0.024**
T2-Identified motivation	*-0.495*	*-2.217*	*0.030*
T2-External regulator	0.194	1.208	0.231
T2-Amotivation	0.086	0.568	0.572
T3-Social identification	-0.199	-1.077	0.286
T3-Flow	0.181	0.835	0.407
T3-Self-rated performance	-0.181	-0.969	0.336
T3-Intrinsic motivation	-0.108	-0.541	0.590
T3-Identified motivation	0.378	2.046	0.045
T3-External regulator	-0.036	-0.211	0.834
T3-Amotivation	0.069	0.464	0.644

Table 1. Multiple linear regression model with Team performance as dependent variable and all individual variables (motivation, flow, social identification, self-rated performance) collected at T1, T2 and T3 as predictors. Significant negative predictors are highlighted in orange and italics and significant positive predictors are highlighted in green and bold.

Predictors	Standardized coefficient	t	p
T1-Intrinsic motivation	0,309	1,989	0,051
T1-Identified motivation	-0,285	-1,588	0,118
T1-External regulator	0,124	0,809	0,422
T1-Amotivation	-0,113	-0,639	0,525
T2-Social identification	-0,228	-1,339	0,186
T2-Flow	0,088	0,395	0,694
T2-Self-rated performance	-0,368	-1,977	0,053
T2-Intrinsic motivation	0,032	0,141	0,889
T2-Identified motivation	0,071	0,302	0,764
T2-External regulator	0,236	1,353	0,181
T2-Amotivation	-0,173	-1,003	0,320
T3-Social identification	0,245	1,251	0,216

T3-Flow	0,205	0,815	0,418
T3-Self-rated performance	0,134	0,661	0,511
T3-Intrinsic motivation	*-0,624*	*-2,757*	*0,008*
T3-Identified motivation	0,060	0,305	0,761
T3-External regulator	-0,161	-0,893	0,376
T3-Amotivation	-0,082	-0,476	0,636

Table 2. Multiple linear regression model with Individual performance as dependent variable and all individual variables (motivation, flow, social identification, self-rated performance) collected at T1, T2 and T3 as predictors. Significant negative predictor is highlighted in orange and italics.

The results emphasize only one significant negative predictor (Intrinsic motivation at T3) and no significant positive predictor, although intrinsic motivation at T1 is close to significance.

Discussion

The results regarding time course of motivation throughout the project seem very positive, as intrinsic motivation increased all along the three measurement points and identified motivation increased between T2 and T3. These two kinds of motivation are the most integrated ones according to self-determination theory. On the contrary, the least integrated levels of motivation we measured (external regulators and amotivation) did not vary during the project. The increase of integrated levels of motivation suggests that students experienced more and more satisfaction during the course of the project. The observed means of intrinsic and identified motivation show middle to high scores. External motivation shows similar levels, which highlights that students expect not only pleasure from this project, but also external rewards associated to project achievement. In a professional learning context, rewards such as tutor recognition, jury members' evaluations and final grade remain meaningful. In this respect, we observed that the importance of these external regulators did not decrease with time. Regarding amotivation, the scores we collected appear particularly low, which is also a positive result, as students are expected to exhibit engagement in their curriculum.

Consistently, flow and self-rated performance showed high scores and increased between T2 and T3. This first set of results is in line with hypothesis H1 that we called "positive hypothesis". H1 mainly relied on the assumption that the situation of performing PBL remotely would support autonomy and competence needs, therefore stimulating intrinsic motivation. Flow may have been fostered because of the personal and familiar home environment in which students worked. This result may not be generalizable to all kinds of populations, be they students or workers, as the lockdown also increased social-class-based inequalities related to learning/working conditions at home (Goudeau et al., 2021).

In our sample learners, motivation and flow were high and may also explain the level of self-rated performance. Furthermore, the level of group identification was also high and increased between T2 and T3, which was unexpected. The latter result rules out hypothesis H2 that assumed that students' need for relatedness would be under-satisfied during remote PBL. This remarkable result may be related to the special ability of Millennials to network through social media: CESI students are used to setting up community tools such as Messenger groups, WhatsApp groups, and Discord groups as soon as during their first week in the school. These groups coexist at different levels (teams, local groups, even national groups). These tools, being parts of their Personal Learning Environment, were heavily used during the lockdown (Blandin, 2020).

The multiple regression analysis to predict team performance produced a complex pattern of results. We should first mention that none of the motivational variables measured in T1 appears as a significant predictor of the final performance of teams. T1 variables were collected the very first day of the project and were supposed to assess their motivation for innovation a priori. In this study, it seems that there was no motivational precondition to team performance. However, in T2 (at the middle of the project), intrinsic motivation and self-rated performance appear as key to lead teams to high performance at the final defenses. Teams that experienced highest flow levels and strong identified motivation did not perform so well at the final defenses. This can be interpreted in light of some free comments delivered by students during the project feedback: some of them expressed frustration that the project duration was too short to properly implement the notions studied. Therefore, one may speculate that those who were too deeply focused (flow) at T2 ran out of time to prepare the final defenses. Those who realized at T2 the importance of the subject for their future career (identified motivation) may have felt this kind of frustration and delayed their convergence for the final deliverables. On the contrary, identified motivation at T3 appeared as a significant positive predictor of teams' final performance. This kind of motivation accounting for consciously valued goals may have helped students to take actions for performing high during the final defenses.

The multiple regression we ran to predict individual performance (learning outcomes after 5 months) shows unexpected results: the only significant predictor is intrinsic motivation at T3, and this is a negative predictor. In other words, the more the students were intrinsically motivated at the end of their project, the less they retained the conceptual notions associated to the project topic. In parallel, even though it does not reach significance, the level of intrinsic motivation at T1 seems to positively influence the final learning outcomes. Taken together, these two results suggest that the conceptual framework and the concrete achievements of the project should not be confused. Students who were intrinsically motivated at T1 (the very first day of the program) were interested in the subject matter in itself (here: innovation), which may have helped them acquire the related concepts (definition, strategies, methods). On the contrary, students highly motivated at the end of their project may have been interested in concrete achievements and engaged in euphoria of creation regardless of any conceptual framework.

From the teachers' viewpoint, our results can be used to elaborate guidelines to stimulate students' motivation at the right time and in the right direction for future PBL programs dedicated to innovation. It seems interesting to stimulate intrinsic motivation for the subject matter (and not only the project), in the aim to support future learning outcomes. Regarding the topic of innovation, this can be done through, for example, well-chosen conferences giving students an overview of what innovation has brought to mankind in the history, how innovation can help society face future challenges (climate change, pandemics, sociodemographic development,…) and thereby the general purpose of innovation for the world. Intrinsic motivation should also be stimulated in the course of the program in a more focused way and applied to each team's project, to maximize the final collective performance. To do so, it could be useful to introduce in the middle of the project targeted exercises to support the search for meaningful goals for their project and for the innovation process. For example, reflecting on the Golden Circle (Sinek, 2011) of their project can help them to identify individual and collective intrinsic motivators. Finally, it seems interesting to enhance identified motivation at the end of the project in order to engage teams towards a more effective delivery of the project. This can be done by emphasizing the target skills to acquire, what they will bring to their curriculum and to their future career.

Conclusion

The positive results we obtained regarding intrinsic and identified motivation during remote PBL may be a consequence of an extra-engagement due to the unprecedented situation of sanitary crisis and the willingness to fight this global twist of fate. Such extra-engagement was indeed observed within the overall working population of France during the months of March to May 2020, according to a survey performed on more than 213,000 collaborators from small, middle and large French companies (Supermood, 2020). This phenomenon is interpreted as partly resulting from a sort of gratitude for being able to maintain their professional activities despite the detrimental context. Some of our students informally expressed the same kind of gratitude for our school and the pedagogical continuity that was implemented. However, France experienced a second lockdown in the months of November – December 2020, and it is very likely that the general mindset of the working and studying population was different from the first lockdown, with more boredom and less fighting spirit.

The predictive models we obtained for team performance and individual learning outcomes may be independent from the specific work conditions. We expect the effects of intrinsic and identified motivation to be replicable also in face-to-face PBL conditions, and hope that our recommendations to support students' motivation would be relevant anyway. However, it remains desirable to conduct further similar studies in various conditions to strengthen our results.

This study was performed during the unique situation of the first lockdown due to Covid-19. The initial aim of monitoring students' motivation, flow, social identification and self-rated performance during their first remote PBL experience produced insights that can be reused for improving not only remote but also face-to-face education. Like in an innovation process, the constraints introduced by the pandemics can be viewed as opportunities to invent better training situations stimulating motivation and meaningfulness for young stakeholders.

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Appendix 1

		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
	Schedule	Phase 1 « to seek »			Phase 2 « to play »						
Morning (4 hours)	8:30 to 9	Questionnaire T1 Introduction	Play	Autonomy	Conference 6	Questionnaire T2	Autonomy	Mentorship	Autonomy	Autonomy	Questionnaire T3
	9 to 9:30	Workshop 1	Autonomy		Autonomy	Autonomy					Defenses (French and English)
	9 :30 to 10										
	10 to 10:30										
	10:30 to 11		Conference 4								
	11 to 11:30			Autonomy							
	11:30 to 12	Conference 1	Autonomy			Conference 7					
	12 to 12:30			Intermediate Deliverable 3	Final Deliverable 1					Final Deliverable 4	
Afternoon (4 hours)	13:30 to 14	Autonomy	Autonomy	REX phase 1		Autonomy	Autonomy	Autonomy	CCTL BM		REX project
	14 to 14:30	Conference 2							CCTL Innovation		
	14:30 to 15			Subject proposals					Autonomy		
	15 to 15:30	Workshop 2	Conference 5								
	15:30 to 16										
	16 to 16:30	Conference 3	Workshop 3			Final Deliverable 2					
	16:30 to 17										
	17 to 17:30	Intermediate deliverable 1	Intermediate deliverable 2				Final Deliverable 3				