TITLE: THE ASSOCIATION OF SELF-DETERMINATION WITH STUDENT ENGAGEMENT MODERATED BY TEACHER SCAFFOLDING IN A PROJECT-BASED LEARNING (PBL) CASE

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ABSTRACT:

Few studies provide conceptual frameworks that help teachers make decisions about the scaffolding they will offer their students in project-based learning (PBL) processes. To address this deficiency, an adaptation of the motivational development selfsystem model was used and a PBL experience involving high school students who had to

create an electric vehicle that used solar energy was analysed© . Applying a multi-group analysis with structural equations, in general, it was observed that the continued support of the teacher in the project activities strengthened the association of students' self-determination with their affective and cognitive engagement. The data suggest that scaffolding can compensate for deficits in self-efficacy, relationship and autonomy of the group of students. This study provides a model that can bevalidated in experimental investigations in which the level of selfdetermination of students is controlled.

Keywords: Project-based learning; preuniversity education; engineering education; scaffolding; group autonomy

1. Introduction

Project Based Learning (PBL) is generally considered an alternative to traditional, teacher- led instruction (Chen, Kolmos, and Du 2020). PBL arises from the needs of educational praxis at the beginning of the 20th century. Education expert William H. Kilpatrick made the concept famous through: "The Project Method" (1918). This methodology allows students to acquire key knowledge and skills by developing projects that respond to reallife problems.

The PBL approach translates into a student-centred©environment with greater engage-ment and motivation (Sukerti, Yuliantini, and Susana 2018; Robinson 2013). Research has shown that student engagement is positively related to achievement, and that disen- gagement leads to poor academic outcomes in a variety of subjects (Fredricks,

Blumenfeld, and Paris 2004). However, a project-based approach does not always produce higher engagement and results (Johnson and Delawsky 2013). In PBL students work on projects independently and academic staff are available at the request of students as a human resource (Chowdhury 2015). So, teachers need to support learning by scaffolding instruction and guiding students to make tasks more manageable (Blumenfeld et al. 1991). Some studies have highlighted the relevance of the teacher's role (e.g©. Chowdhury 2015) in the initial and critical phases of the process, providing feedback and support (Lee et al. 2016), making students feel effective and facilitating group collaboration (Zhang, Xie, and Li 2018).

However, for the instructor, one of the challenges of project-based learning is determining how much support to apply (van. Rooij 2009). But to make this decision it is necessary to have comprehensive frameworks that provide information. The objective of this study was to provide a conceptual framework that helps teachers to regulate the application of scaffolds.

The authors using (a) the self-system theory of emotional development (Skinner et al. 2008) that postulates the direct effect of student self-efficacy, relationships and group autonomy on engagement to the learning task, and (b) the premise that scaffolding does not directly influence commitment, they posed the following hypothesis: the amount of teacher support during the development of the project will moderate (strengthen or weaken) the effect of self-efficacy, communication between peers and the autonomy of the group on the commitment of the students.

In pursuit of this objective an experimental framework was developed by designing a PBL model focused on environmental sustainability. The methodological practices of

the Sustainable Urban Race (SUR) Project were analysed. The principal idea of the SUR project is to encourage students in pre-university educational levels in the southwest of the Iberian Peninsula to study scientific and technical education. In this project, the students must create, during the academic year, an electrical vehicle that uses solar energy.

2. Background

2.1. Student engagement and self-determination

Student engagement is a construct that describes malleable aspects of conduct that are beneficial for learning and adaptation within the school context. It functions as a project started by the student towards the achievement of academic/educational goals (Jang, Kim, and Reeve 2012; Ladd and Dinella 2009; Lippmann 2013; Rocca 2010). Student engagement is a multidimensional construct comprised by interconnected aspects that are mutually reinforced. Some reviewers have suggested that it is useful to distinguish affective, behavioura©l, and cognitive forms (Christenson, Reschly, and Wylie 2012; Fredricks, Blumenfeld, and Paris 2004; Fredricks et al. 2016; Wang et al. 2016). The under lying assumption is that high-quality learning is the result of behaviours and emotions, such as exertion, persistence, interest, and enjoyment that reflect a motivation to development the project. Likewise, from a processual approach, there are studies that haves hown internal dynamics between the dimensions of engagement (E. Skinner et al. 2008), showing that emotions feed behaviours in the classroom. This evidence empirically reinforces the assumptions of theories such as self-determination (Deci and Ryan 1985) that suggest that emotions such as interest and enthusiasm fuel behaviours such as effort and persistence.

To understand the mechanisms that explain student engagement in relation to aca demic performance, the Self-System Model of Motivational Development (SSMMD). Skinner et al. (2008) based on previous findings (Connell and Wellborn 1991; Deci and Ryan 1985; Skinner and Wellborn 1997) through a longitudinal study with elementary school students in public schools in the United States, showed the interest of this model for delving into the personal and learning context factors associated with changes in engagement. In this model, "the developing person is viewed as an active partner in the construction of the self-system from the first moments of life. The self-system is viewed as a set of appraisal processes whereby the individual evaluates his or her status within particular contexts with respect to three fundamental psychological needs: competence, autonomy and relatedness" (Connell and Wellborn 1991, 51). In school contexts, as these three needs are satisfied, the functionality of the class improves, and a psychological wellbeing develops, motivating the students to become engaged with learning (Jang, Kim, and Reeve 2012).

2.2 Project-based learning (PBL) and teacher scaffolding

PBL is an educational method grounded in general theories of knowledge such as situated learning (Lave and Wenger 1991), which states that knowledge must be presented in an authentic context, using settings and applications that would normally involve that knowledge, and includes social interaction and collaboration to solve complex problems (van van Rooij 2009). PBL tends to be a group activity with a timeline, milestones and other formative evaluation steps. The process replicates the commonly used systemic approaches to resolving problems or meeting challenges that are encountered in real life (Donnelly and Fitzmaurice 2005). In PBL, unlike similar

methods (e.g©. problem-based learning), the central focus of the task is for students to develop and apply knowledgeto produce some final product (Prince and Felder 2007).

The PBL approach could mean a student-centred environment with greater engagement and motivation (Sukerti, Yuliantini, and Susana 2018; Robinson 2013). However, a project-based approach does not always produce higher engagement and results (Johnson and Delawsky 2013). PBL is generally a less structured approach than traditional, teacher-led classroom learning and can be conducive to student autonomy and choice within unsupervised work time (Lee et al. 2016). However, working in non- or low- structure environments can entail significant side effects. In such an environment, it is difficult for students to clearly identify project design-flow phases. Furthermore, coopera- tion and collaboration levels are difficult to control, which leads to the lack in clarity of individual work, mentoring and evaluation (Milentijevic, Ciric, and Vojinovic 2008).

Successful implementation of PBL in the classroom lies in the teacher's ability to effectively scaffold student learning, motivate, support, and guide students along the process (Kokotsaki, Menzies, and Wiggins 2016). Some studies have highlighted defining the role of the teacher (e.g. Chowdhury 2015) in the initial and critical phases of the process providing feedback and support (Lee et al. 2016), making students feel effective and facilitating autonomy and group collaboration (Zhang, Xie, and Li 2018).

Therefore, on the one hand, a key feature of PBL is learner control of the process, affording team members the opportunity to design, develop and execute their own vision of what the project processes as well as the final product should be. On the other hand, it is the instructor's job to provide the appropriate amount of scaffolding to

motivate learners, reduce task complexity, provide structure and reduce learner frustration. Based on the concept of zone of proximal development (Vygotsky 1978), scaffolding refers to a process in which the instructor provides assistance to students for tasks or concepts that they are initially unable to grasp on their own. Once the student masters the task or concept, the instructor begins the process of "fading", or the gradual removal of the scaffolding, which allows the student to work independently and collaboratively. Therefore, the amount of scaffolding will depend on the status of the group, i.e. of their competence and capacity for autonomous learning.

3. Hypotheses

Currently, there is a lack of a theoretical framework that provides robust indicators to teachers to know under what circumstances to provide a greater or lesser amount of scaffolding. The SSMMD and knowledge of the dynamics of engagement provide a conceptual framework in which scaffolding can behave as a moderator of the relationship between competence and student autonomy with engagement. In other words, the greater the competence, autonomy and bonding of the group, the less scaffolding will be necessary to increase the affective and cognitive engagement of the students. To test this claim, the authors presented the following empirical arguments.

Although there are numerous evidences that show the relationship between the components of the self-system (autonomy, relationships and self-efficacy) and engagement, there are few studies that attempt to show it in PBL contexts. Kolmos' (2010) findings suggest that for learning to be successful it is crucial to pay attention to students' perceptions of the learning process and environment in PBL. Giving students

157 autonomy, allowing projects to be driven by them and actively involving them in the
158 process, has been empirically shown to bring different benefits to learning
159 (Grassberger and Wilder 2015; Thomas 2000). Among the reported benefits of active
160 participation is increased student engagement and satisfaction (Graham and Crawley
161 2010). The SSMMD posits that increases in engagement and decreases in discontent can
162 be predicted by students' self-perceptions (i.e. satisfaction of self-efficacy, autonomy
163 and relationship needs) (Skinner et al. 2008). All of this leads to the following
164 hypotheses:

165 H1. There is a significant and positive association between the self-efficacy perceived
166 by the students and their affective (H1a) and cognitive engagement (H1b) in learning
167 tasks.

168 H2. There is a significant and positive association between the relationship and their
169 affective (H2a) and cognitive engagement (H2b) in learning tasks.

170 H3. There is a significant and positive association between autonomy and their
171 affective (H3a) and cognitive engagement (H3b) in learning tasks.

172 The student's engagement is a meta-construct comprised by interconnected constructs
173 that are mutually re-enforced (Fredricks et al. 2016; Wang et al. 2016) and is associated
174 with positive academic outcomes (Fredricks, Blumenfeld, and Paris 2004).

175 There are studies that have shown internal dynamics between the dimensions of
176 engagement (Skinner et al. 2008), showing that emotions feed behaviours in the
177 classroom. This evidence constitutes the basis of the following hypothesis:

H4. A high degree of affective engagement will be positively related to a high degree of cognitive engagement.

Many researchers agree that the real strength of PBL lies in the effects of the approach on student engagement (Chowdhury 2015; Kolmos 2010). If students are motivated and engaged, they learn more (Schaddelee and McConnell 2018). Taking into account this evidence, the following hypotheses were proposed:

H5. A high degree of affective engagement will be positively associated with a high degree of technical learning.

H6. A high degree of cognitive engagement will be positively associated with a high degree of technical learning.

Once the analytical and conceptual framework was established, the authors started from the definition of scaffolding as a process in which the instructor provides assistance to the student and once that the student masters the task, the instructor begins a gradual removal of the scaffolding, which allows the student to work independently and collaboratively (Zhang, Xie, and Li 2018). Therefore, the scaffolding must be lower as students acquire competence, and the group acquires autonomy. The hypothesis formulated was the following:

Categorical moderation hypothesis. The relationship between self-determination and student engagement will be strengthened when teachers provide support, so that deficits in group self-efficacy, relationship, and autonomy can be overcome with teacher scaffolding.

4. Method

4.1. Learning context

This study was based on an educational project aimed at pre-university students, called the SUR project, which aims to increase interest in technology and science. SUR is carried out in the southwest of the Iberian Peninsula and aims to promote scientific and technical careers among pre-university students, also trying to bring science, technology and innovation closer to society in general. A network of secondary education centres participates in the SUR project with the goal of creating a vehicle that allows transporting at least one person in an urban environment.

The project seeks to develop engineering skills and transversal skills such as creativity, collaboration, decision-making, work organisation and time management, among others. The phases of the project were as follows

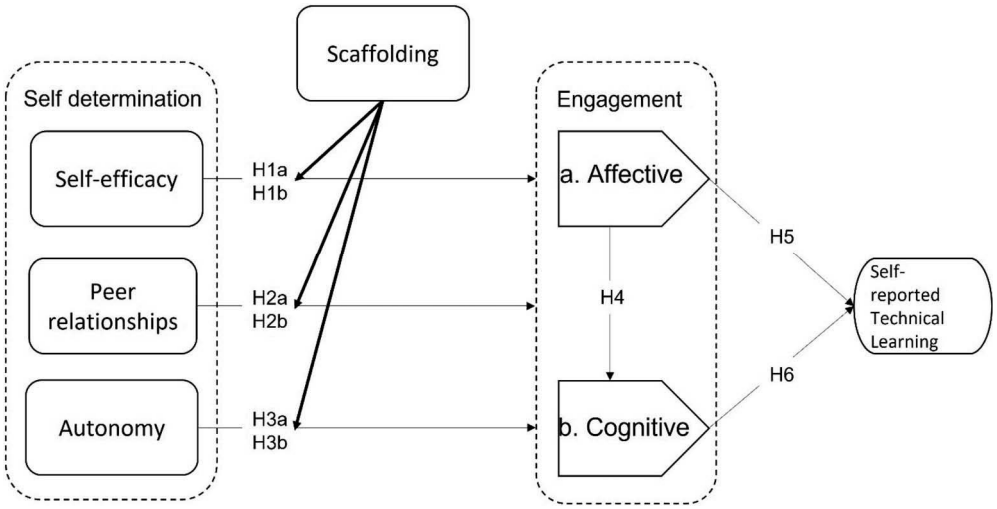


Figure 1. Hypotheses tested.

Technical Conferences. Organised by the university promoting the project, they were the first point of contact with the teachers involved. The act consisted of the presentation of the norms and regulations, the tests to be carried out, the evaluation

criteria and the improvements compared to previous editions. Finally, a series of training courses were presented to update the knowledge of the participating teachers and support their tasks.

Vehicle construction. Participants in this phase must build a 3 or 4 wheeled solar vehicle capable of transporting one person. Furthermore, they must solve some proposed technical challenges, such as the design of a telemetry system. The beginning of this phase started with the visit of project technicians to each school to deliver a development kit (engine, solar panels and other components) and advise participating teachers on topics related to the construction of the vehicle.

Until the date of the race, several visits to schools were made to assess the development of their projects. These visits were useful to solve problems with the construction of the vehicle and with the use of Arduino, the programming platform employed. In some cases, the construction of the vehicle was part of regular classroom subjects, in other cases the project was approached as an extracurricular activity.

Public competition between vehicles. At the end of the academic year, all teams from each school attend this event, held at the university campus, with their prototypes.

4.2. Data collection and participants

The data collection process was carried out in the academic year 2018–2019. The sample was comprised of 83 students, from which 32,5% were at the Compulsory Secondary Education level, 32,5% were in Baccalaureate and 35% were at the Vocational Training level. Moreover, 33% were aged between 14 and 16 years, 60% 17 to 19 years old and 7% were aged 20 years or more. In terms of gender, 67% were male.

239 The data collection was performed as follows: in the first phase of the project, during
240 the technical conferences, the teachers were clearly informed about the objectives of the
241 study. The measuring instrument was provided to the students on the day of the race.
242 It was administered through an online form available on computers in the computer
243 room.

244 Participation was voluntary and anonymity was guaranteed. Five educational centres
245 participated in the study, and each school team had between 13 and 20 participants.

246 *4.3. Measurement*

247 *4.3.1. Measurement of Scaffolding*

248 To measure scaffolding the scale by Project Management Institute (2004) was utilised.
249 A five-point response scale was used, which ranged from 0 (it was not done), 1 (the
250 teacher did it), 2 (we did it with the teacher's help), 3 (it was done in consultation with
251 the teacher) to 4 (we did it all ourselves).

252 Items used were: "at the start of the project, the scope was described: materials,
253 characteristics . . . ", "the project was broken down into phases", "work modules were
254 specified", "activities were specified in each module", "in each activity the person
255 responsible was specified", "in each module/activity the end date was established",
256 "we had to investigate", "new ideas had to be generated", "new solutions had to be
257 sought", "we used templates to control number and percentage of completed tasks"
258 and "we used templates to control the team's work rate". To verify the consistency of
259 the scale, we obtained the Cronbach´s Alpha (α), which was .89 and the average
260 variances extracted (AVE) was .48.

Measurement of Self-determination, the research model was composed of three constructs. (Deci and Ryan 1985):

- Self-Efficacy (SEL) referring to the need of human beings to feel competent in their interactions with the environment through a 3-item scale drawn from the Patterns of Adaptive Learning Survey's academic efficacy measure (Midgley et al. 2000), with responses on a 4-point Likert scale from not at all true to very true. The scale had good reliability (α = .86). The scale used had the following items: "during the course of the project, I felt that I could perform all the tasks that were proposed to me", "I have been sure that I mastered all the contents of the project" and "I thought I did it well even in the most difficult tasks".

- Relationship (RE) refers to the need that people have to feel that they belong to a particular project using a scale designed and validated by Mikami, Boucher, and Humphreys (2005) and recently used by Ruzek et al. (2016) showing the predictive validity of the measure on behavioural engagement reported by students. The scale developed showed acceptable reliability (α = .74). The scale used contained 2 items: "how many colleagues from the team respected and listened to your opinions?" and "with how many colleagues from the project did you get along?" were also used. Student replies were arranged on a 4-point Likert scale ranging from everybody to nobody.

- Autonomy (AU) notes the level to which students performed tasks autonomously in their classroom through an adaptation of the scale used Ruzek et al. (2016) with α = .80. The predictive validity of this measure with observed student

283 participation and self- reported student participation has been demonstrated by
284 previous research (Hafen et al. 2012). The scale designed for this project had moderate
285 reliability (α = .65) and was comprised of items such as "we make decisions on how to
286 develop it", "we decided how to carry out group activities", and "we had very
287 stimulating discussions". For the answers, a 4-point Likert scale was used ranging from
288 not at all true to very true.

289 *4.3.2. Measurement of Engagement*

290 To measure this multi-dimensional construct, the scales by (Fredricks, Blumenfeld, and
291 Paris 2004; Fredricks et al. 2016) and Wang et al. (2016) were used.

292 The dimensions measured were affective engagement (AE) (e.g. "I liked participating
293 in the project", "I enjoyed learning new things about the subject", "I wanted to
294 understand what we did during the project" and "I felt good when we were working"),
295 and cognitive engagement (CE) (e.g. "I reviewed the work to make sure it was okay",
296 "I thought of different ways to solve a task", "I was trying to connect what we did with
297 what I already knew" or "I tried to learn from my mistakes when something went
298 wrong"). These dimensions were measured through four-point scales that ranged from
299 1 (strongly dis- agree) to 4 (totally agree.).

300 In terms of Cronbach's Alpha analysis and average variance extracted, EE α was .91
301 and AVE was .81. and CE α was .85 and AVE was .74.

302 *4.3.3. Measurement of Self-reported Technical Learning (STL)*

303 To measure the level of technical learning (TEL) the learning objectives set by the
304 project's organisers were used. In this sense, a four-point response scale was used,

305 which ranged from 1 (nothing) to 4 (a lot). Items such as "I have learned to design and
306 build a reliable prototype, capable of transporting a person, without breaking", "use of
307 specific software for structure design", "design and build simple electronic circuits",
308 "install vehicle wiring", "install the photovoltaic panels and connect them", "install
309 battery connection terminals", "handle tools" or "apply basic programming principles
310 through the ARDUINO platform" were used to measure TEL. In TEL Cronbach´s
311 Alpha was .91 and AVE was .62.

312 Appendix shows he results of the analysis of validity and reliability of each construct.

313 *4.4. Data analysist*

314 The hypothesis was tested using structural equation modelling (SEM) with AMOS
315 software (Figure 2). According to this method, each theory consists of a group of
316 correlations, and if the theory is valid, the correlation patterns (assumptions) can be
317 reproduced through empirical data (Byrne, 2013).

318 Simultaneously analysing all the variables and their relationships, the SEM statistically
319 tests the theoretical model analysed©, to verify the consistency of the proposed model
320 with the data. The model supports the plausibility of the relationships presented, if the
321 goodness of fit is adequate; however, if it is not adequate, the plausibility of the model
322 is rejected. The usual indices of the three fit categories of the model were used to
323 measure the goodness of fit of the model (Hair et al. 2006) (absolute, parsimonious and
324 incremental). Following the recommendations of Hair et al. (2006) the following
325 adjustment criteria were established: for N observed variables ≤ 12 and N < 250. The
326 root means square error of approximation (RMSEA) was used (0< RMSEA<0.08). For
327 the incremental measurement of fit, the comparative fit index (CFI) was used (CFI ≥

0,97). Lastly, for the measurement of parsimonious fit, the normed $\chi 2$ ($\chi 2$/df) was used (1< $\chi 2$/df<2).

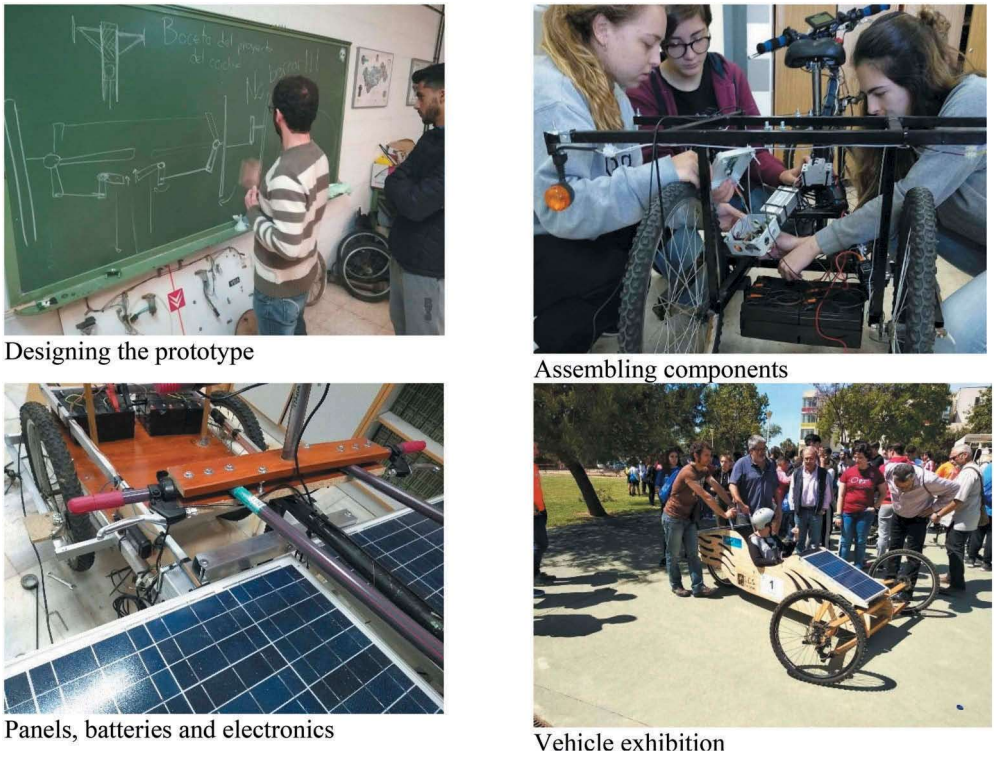


Figure 2. Images of the SUR project.

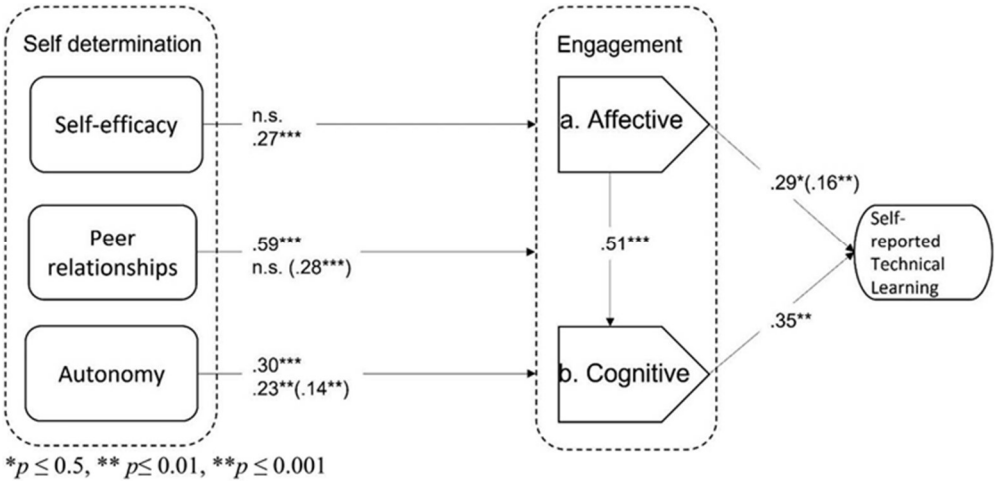


Figure 3. Relationship structure of the basic model. Note: Numbers in parentheses represent indirect associations. *p ≤ 0.5, ** p≤ 0.01, **p ≤ 0.001

To test the categorical moderation hypothesis, a multigroup analysis was performed to test the invariance (equivalence) of the model parameters. This type of analysis allows us to identify the moderating effect while controlling the groups of students according to the amount of teaching support received. Two groups were created for analysis. To create the groups, a variable was created with the mean value of the "scaffolding" scale, in such a way that mean values ≥ 3 – which implied greater autonomy of the student – were coded with 1, and the values means < 3 – which implied a greater teacher presence – were coded with 2. The groups were called "weak support" and "strong support". The "weak support" group consisted of 39 students and the "strong support" group consisted of 44 students.

Table 1 shows the composition of the groups. In the analysis of the percentages in the different activities of the project, it can be observed that the weak scaffold group used to act autonomously and in consultation with the teachers, while the strong scaffold group in almost all the project activities acted mainly with the help of the teacher.

Measurement invariance refers to the degree to which the parameters of the measurement model are similar in both groups and was evaluated at its low levels: structural weights (i.e. invariance of H1 (a & b), H2 (a & b), and H3 (a & b) and structural intercepts (invariance of affective and cognitive engagement, and technical learning). To analyse the invariance the tests recommended by Byrne (2013) were used, starting from the determination of a good fit for the multigroup configurational model, this model will serve as the basis for analysing the rest of the more restrictive models. Previous research studies have used the Chi-square difference ($\Delta\chi 2$) test to compare restrictive models. However, given the sensitivity of $\chi 2$ to sample size and non-

normality (Hair et al. 2006), Cheung and Rensvold (2002) proposed the increase in CFI (ΔCFI), to determine whether the compared models are equivalent. In this sense, when the difference between the CFI of the two models is greater than 0.01, the less restrictive restricted model is accepted and the other rejected. Therefore, if the invariance were confirmed, the moderation hypothesis would be rejected.

	It was not done (0)		The teacher did it (1)		Teacher's support (2)		Consulting the teacher (3)		We did it all (4)	
	Weak	Strong	Weak	Strong	Weak	Strong	Weak	Strong	Weak	Strong
At the start of the project, the scope was described: materials, characteristics...	2.6	2.3	5.1	20.5	25.6	*50.0*	20.5	20.5	*46.2*	6.8
The project was broken down into phases	0.0	6.8	2.6	9.1	51.3	*81.8*	0.0	0.0	*46.2*	2.3
Work "modules" were specified	2.6	4.5	0.0	20.5	41.0	*72.7*	51.3	0.0	0.0	2.3
Activities were specified in each "module"	2.6	2.3	0.0		*59.0*	*95.5*	38.5	2.3	0.0	0.0
In each activity the person responsible was specified	2.6	2.3	5.1	13.6	35.9	*72.7*	0.0	0.0	*56.4*	11.4
In each module/activity the end date was established	0.0	18.2	0.0	0.0	*53.8*	*77.3*	43.6	4.5	0.0	0.0
We had to investigate	0.0	6.8	0.0	0.0	35.9	*86.4*	*59.0*	6.8	0.0	0.0
New ideas had to be generated	0.0	2.3	0.0	0.0	41.0	*95.5*	*59.0*	2.3	0.0	0.0
New solutions had to be sought	0.0	2.3	0.0	0.0	41.0	*97.7*	*59.0*	0.0	0.0	0.0
To control the number and percentage of completed tasks	10.3	13.6	0.0	0.0	51.3	*86.4*	*38.5*	0.0	0.0	0.0
The pace of work of the team	5.1	11.4	0.0	0.0	17.9	*70.5*	*76.9*	18.2	0.0	0.0

Note: The italics highlights the highest percentages of each activity in both groups

Table 1. Percentages of activity in the project according to strong and weak scaffolding.

5. Results

Firstly, a statistical analysis was carried out to examine the assumption of normality of the variables used in the structural equations model. In addition, asymmetry and kurtosis analyses were performed (see Table 2). According to Curran, West, and Finch (1996) these analyses establish the limits, in absolute values, until the behaviour can be considered close to normal, for values between 2 for asymmetry and 7 for kurtosis. As the results showed that the values of both statistical tests complied with this rule, the normality condition was accepted.

Second, the descriptive results showed that the mean values of the variables of the construct of self-determination, engagement and self-reported learning outcomes were higher in the group that acted with more autonomy than in the group with more constant support.

To improve the good fit of the model, a re-specification of the original model was performed, eliminating variables whose factor loads did not exceed the minimum required value of 0.50. So that the RE variable was modified and lost one item.

	Mean (SD)												
	Total (n = 83)	Weak (n = 39)	Strong (n = 44)	Asy.	Kurt	Min	Max	1	2	3	4	5	6
1. Self-efficacy	2.99 (.76)	3.14 (.76)	2.78(.79)	- .19	–1.02	1.3	4	*.88*					
2. Relationships	3.04 (.52)	3.62 (.48)	3.59(.60)	- .04	1.91	1	4	.50**	*.89*				
3. Autonomy	3.26 (.48)	3.36 (.47)	3.17 (.60)	.04	- .97	2.2	4	.52**	.43**	*.68*			
4. Affective engagement	3.62 (.51)	3.66 (.47)	3.52 (.68)	–1.29	1.18	2	4	.33**	.39**	.36**	*.83*		
5. Cognitive engagement	3.37 (.55)	3.48 (.46)	3.23 (.75)	- .72	.96	1	4	.51**	.47**	.54**	.63**	*.82*	
6. Self-reported technical learning	2.85 (.72)	3.12 (.55)	2.89 (.79)	- .48	.32	1	4	.27**	.29**	.26**	.33**	.36**	*.78*

Table 2. Descriptive results of the constructs and discriminant validity analysis.

5.1. Basic model

Figure 3 show the regression indices for all the associations established in the model, as well as the variance explained for affective and cognitive engagement, as well as technical learning. Table 3 also shows the indirect effects that indicates the effect of a determinant variable on another one, through its effect on other variables that intervene in the model. Indirect effects analysis can provide new information needed for a more detailed under- standing of the relationships between the variables in the model.

391 Likewise, the model explained 57% of the variance found in affective engagement, 68%

392 in cognitive engagement, and 35% in technical learning

Hypothesis	Beta		
	Direct effects	Indirect effects	Total effects
H1a. Self-efficacy – Affective engagement	-		
H1b. Self-efficacy – Cognitive engagement	.27***		.27
H2a. Peer relationships – Affective engagement	.59***		.59
H2b. Peer relationships – Cognitive engagement	-	.28***	.28
H3a. Autonomy – Affective engagement	.30***		.30
H3b. Autonomy – Cognitive engagement	.23**	.14**	.37
H4. Affective engagement – Cognitive engagement	.51***		.51
H5. Affective engagement – Technical learning	.29*	.16**	.45
H6. Cognitive engagement – Technical learning	.35**		.35
R^2 Affective engagement		.57	
R^2 Cognitive engagement		.68	
R^2 Technical learning		.35	
$\chi 2/df$		1.834	
p		.103	
IFI		.983	
CFI		.983	
RMSEA		.10 (.00-.17)	

*p ≤ 0.5, ** p ≤ 0.01, **p ≤ 0.001

Note: The italics represent the square root of the AVE, being greater than the correlation with the rest of the variables in the model

393

394 Table 3. Direct and indirect associations in basic structural model.

395 After testing the validity of the causal structure for the basic model, the indices of

396 adjustment obtained were acceptable: $\chi 2/df = 1.834$, IFI = 0.983 and CFI = 0.983.

397 However, the RMSEA values were high, probably due to their sensitivity to the sample

398 size (e.g. Morata-Ramirez, et al., 2015).

399 Once the proper adjustment of the model was demonstrated, the resulting relation-

400 ships were analysed to verify the validity of the hypotheses and thus dictate the

401 predictive capacity of the model.

402 First, the model did not support associations of self-efficacy with affective engagement

403 (H1a) and of relationships with cognitive engagement (H2b). However, an indirect

404 asso- ciation of the relationships with cognitive engagement mediated by affective

405 engage- ment was observed ($\beta = .28$, $p < .001$).

406 In contrast, affective engagement was significantly associated with relationships (H2a)
407 (β = .59, p < .001) and group autonomy (H3a) (β = .30, p < .001). Likewise, cognitive
408 engagement was strongly associated with student self-efficacy (H1b) (β = .27, p < .001)
409 and group autonomy (H3b) (β = .23, p < .01). Group autonomy was also indirectly
410 associated with cognitive engagement partially mediated by affective engagement (β =
411 .14,p< .01). Lastly, a strong association between affective and cognitive engagement
412 (H4) (β = .51, p < .001) was found. Also, the association of affective (H5) (β = .29, p < .05)
413 and cognitive engagement (H6) (β = .35, p < .01) with learning was confirmed.
414 However, an indirect association of affective engagement with self-reported technical
415 learning mediated by cognitive engagement was also observed (β = .16, p < .01).

416 *5.2. Categorically moderate model*

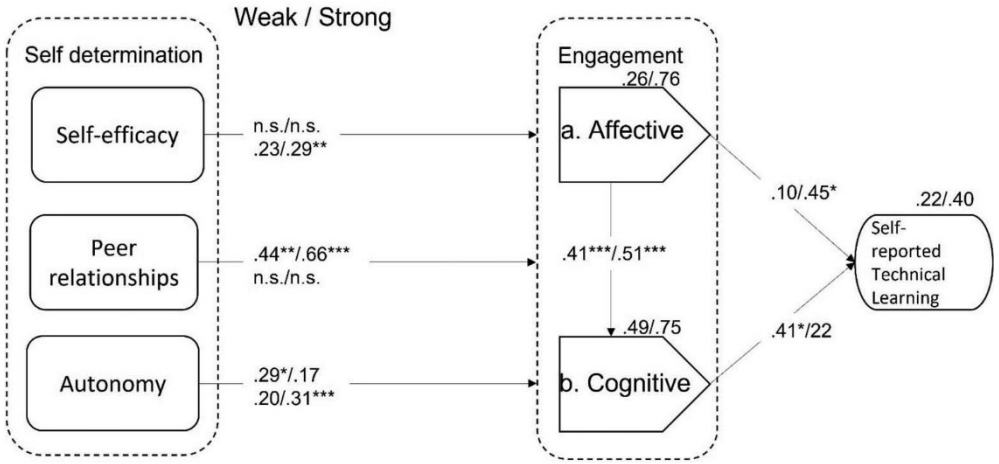
417 The moderate relationship model seeks to verify to what extent the type and amount of
418 scaffolding strengthens or weakens the effect of self-determination (self-efficacy,
419 relation- ships and autonomy) on engagement. Table 4 provides the results of the
420 moderate model by type of scaffold (weak or strong). Figure 4 shows the structure of
421 relationships.

422 The multigroup models showed acceptable fit indices: χ2/df = 1.452; RMSEA = 0.075
423 (90% confidence interval = 0.000, 0.150); IFI = 0.981; and CFI = 0.979.

	Weak Support	Strong Support	Critical ratio
H1a. Self-efficacy → Affective engagement	-	-	-
H1b. Self-efficacy → Cognitive engagement	.23	.29**	1.05
H2a. Peer relationships → Affective engagement	.44**	.66***	1.822*
H2b. Peer relationships → Cognitive engagement	-	-	-
H3a. Autonomy → Affective engagement	.29*	.17	−0.45
H3b. Autonomy → Cognitive engagement	.20	.31***	0.851
H4. Affective engagement → Cognitive engagement	.41***	.56***	1.276
H5. Affective engagement → Technical learning	.10	.45*	−0.857
H6. Cognitive engagement → Technical learning	.41*	.22	1.345
R^2 Affective engagement		.73/.26	
R^2 Cognitive engagement		.75/.49	
R^2 Technical learning		.40/.22	
$\chi 2/df$		1.452	
IFI		.981	
CFI		.979	
RMSEA		.075 (.000-.153)	
Δ ($\chi^2_{configural}$, $\chi^2_{structural\ weights}$) ($p$)		10.540 (.160)	
Δ ($CFI_{configural}$, $CFI_{structural\ weights}$)		.016	
Δ ($\chi^2_{configural}$, $\chi^2_{structural\ intercepts}$) ($p$)		8.036 (.045)	
Δ ($CFI_{configural}$, $CFI_{structural\ intercepts}$)		.023	

*$p \leq 0.5$, ** $p \leq 0.01$, **$p \leq 0.001$

Table 4. Hypotheses in multi-group analysis and critical ratio.



*$p \leq 0.5$, ** $p \leq 0.01$, **$p \leq 0.001$

Figure 4. Relationship structure of the multigroup model. *p ≤ 0.5, ** p≤ 0.01, **p ≤ 0.001. Note: The data to the left of the bar represents the group with weak scaffolding, the data to the right of the bar represents the group with strong scaffolding

Multigroup regression analyses showed a strengthening of the connection between self-efficacy and cognitive engagement (H1b) when the students acted regularly with the teacher's support (βweak = .23; βstrong = .29***). These data suggest that when students worked more autonomously and in consultation with teachers, they depended less on self-efficacy to become cognitively engaged in the project. On the other hand, the less autonomous students to become cognitively engaged depended more on their self- efficacy, which could be strengthened by the teaching support received.

Similarly, the effect of autonomy on cognitive engagement (H3b) was strengthened when there was "strong" scaffolding. I.e. when the group received constant support from the teachers, the need for the group to feel autonomous to engage cognitively increased (βweak = .20; βstrong = .31***). Likewise, for students who depended more on teacher support, self-efficacy and autonomy to engage cognitively were more decisive than for more autonomous students. The data suggest that frequent teacher support could compensate for the group's lack of self-efficacy and autonomy.

Regarding affective engagement, the multi-group analysis showed a strengthening of the connection of the group's relationships with affective engagement (H2a) when there was strong scaffolding (βweak = .44**; βstrong = .66***). Likewise, when there was strong scaffolding, the connection between autonomy and affective engagement (H3a) was weakened (βweak = .29 **; βstrong = .17). These data, on the one hand, suggest that when the group received constant support from the teachers, it was more decisive to have a strong cohesion to engage affectively than when the group acted with more autonomy. On the other hand, to get emotionally engaged, for the more autonomous

455 groups it was more decisive to feel autonomous than for the groups that acted with
456 more constant support.

457 Finally, the invariance analysis showed that the regression parameters and the variance
458 of the affective commitment, cognitive and technical learning variables were not
459 equivalent. That is, with respect to the regression parameters, both the difference of $\chi 2$
460 (Δ p = .160) and CFI (Δ CFI = .016) exceeded the admissible indices. Likewise, regarding
461 the variance, also the difference of $\chi 2$ (Δ p = .045) as CFI (Δ CFI = .023) had higher
462 values. Therefore, these data allow us to conclude that the type and amount of
463 scaffolding moderated the connections between the student's self-determination (self-
464 efficacy, relationships and group autonomy) and the students' engagement (affective
465 and cognitive).

466 **6. Discussion**

467 PBL is a methodological approach that involves the design of meaningful and
468 stimulating learning experiences for students, that is, that connect with the students'
469 maturity level and with their socio-cultural context (Donnelly and Fitzmaurice 2005).
470 From this approach, the student is the centre of the learning process, learning in groups
471 and autonomously (Lee et al. 2016; Robinson 2013; Sukerti, Yuliantini, and Susana
472 2018). Also, in this learning context, the support of the teacher -scaffolding- may
473 stimulate the optimal development of these dynamics (Zhang, Xie, and Li 2018).
474 However, few empirical studies attempt to conceptualise©scaffolding in a project-
475 based learning context.

476 The authors used the self-system model of motivational development (E. Skinner et al.

2008) because it is a validated model with a long history of cognitive studies and applied to the learning context (see Connell and Wellborn 1991). In this model, the student's self-determination (competence, social relations and autonomy) is the factor that directly influences the students' engagement to the learning task. Likewise, the scaffolding from the constructivist approach is understood as an interface between the student (self) and the task (action), making students feel capable of solving the task by themselves (Zhang, Xie, and Li 2018). This study used a research model that placed scaffolding as a variable that can moderate (strengthening or weakening) the connection between self-determination and engagement to the learning task. I.e. this study uses a notion of scaffolding that considers aspects of the self and complements the vision of the development potential of students.

This research empirically shows the general capacity of the scaffolding type to moderate (strengthen or weaken) the connection of self-determination with the affective and cognitive engagement of students

6.1. Regarding scaffolding and affective engagement

In groups with a more constant scaffolding, communication between peers had a stronger association with positive emotions than in groups more autonomous. Therefore, the constant presence of teacher support strengthened the importance of team relationships in awakening interest in the task. These data suggest that the teacher's scaffolding could compensate for the lack of cohesion of the group and stimulate it affectively.

Also, in groups with constant scaffolding, group autonomy had a weaker connection with positive emotions than in groups more autonomous. The continued support of the

500 teacher could reduce the capacity of the autonomy to arouse interest in the learning
501 task. These data suggest that in conditions in which the group has the continued
502 support of the teacher, there must be a good relationship between the classmates so
503 that they feel emotionally engaged. On the other hand, for students who act with more
504 autonomy and in consultation with the teaching staff, it is especially relevant that they
505 feel autonomous.

506 *6.2. Regarding scaffolding and cognitive engagement*

507 In groups with constant support, self-efficacy and autonomy have a stronger
508 association with cognitive action than in more autonomous groups. I.e. the continued
509 support of the teacher strengthened the association of self-efficacy and autonomy for
510 students with cognitive engagement. These data suggest that for students who have
511 constant teaching support to have good results, they must feel effective in carrying out
512 the project and feel capable of working independently. In any case, teachers must be
513 vigilant to compensate for the shortcomings of the group of students.

514 *6.3. Regarding scaffolding and student self-determination*

515 The data showed that the variance of affective, cognitive engagement and self-reported
516 technical learning is notably higher in the group of students who received more
517 constant support. These results showed that when students worked with the teacher's
518 support, the students' engagement is strongly determined by their self-efficacy with
519 the task, by their team relationships and by the autonomy of the group. The data also
520 showed that it was the students with less self-determination who had continued
521 support during the project, which allows us to suppose that the scaffolding acted

compensating for the deficits of self-efficacy, relationships and the group's capacity for autonomy.

In contrast, a weak scaffolding attenuates the importance of student self- determination in the model. It was the students with greater self-determination who worked with greater autonomy and received teaching support upon request. The data suggest that for students with greater self-determination there may be other more determining aspects of the student's engagement to the project (for example, Ruzek et al. 2016; Shernoff et al. 2016; Skinner et al. 2008) that do unnecessary ongoing support.

6.4. Regarding scaffolding, engagement and self-reported learning

The results of the multi-group analysis also revealed information on the dynamics between engagement and self-reported learning outcomes. In the groups that received weak scaffolding during the project, self-reported learning was directly associated with the cognitive activity. In contrast, in the groups that received strong scaffolding, self-reported learning was directly associated with affective engagement and interest of the students in the task. This data highlights that it is extremely important for groups operating with constant support to feel good and enjoy the project. In contrast, for more autonomous groups, affective engagement can be a mediator for them to become cognitively involved with the learning task.

7. Conclusions

This study uses a research model that places the scaffolding between the subject's self-determination (and his/her group) and the action (engagement), providing reference

parameters regarding the scaffolding for the development of stimulating PBL experiences.

Overall, the data suggest that continued teacher support can strengthen the association of students' self-determination (i.e. self-efficacy, positive group relationships, and autonomous learning ability) with affective and cognitive engagement so that they can achieve positive outcomes. As a practical consequence, if the levels of self-determination are low, it will be necessary for teachers to include a continued support to strengthening the competence, cohesion and autonomy of the group, and to stimulate the affective and cognitive engagement of the students. On the other hand, if the levels of self- determination of the students are high, teaching support at the request of the students will be preferable, strengthening the autonomy of the group and its connection with affective engagement.

The data from this study have shown that the type and amount of adequate scaffolding may be conditioned by the group's ability to learn autonomously. This research work provides a conceptual framework for analysis to deepen the study of scaffolding as a teaching support with two axes of reference: (a) the state of competence, relationship and autonomy of the group, and (b) the degree of engagement to the learning process.

8. Limitations and future studies

The study had a few limitations that could guide researchers in the future. In the first place, the collection of data occurred once, and it would be interesting to conduct longitudinal studies, in order to know the dynamics over time (Cheon and Reeve 2015). In the second place, other qualitative records could be complementary, because personal reports were used in the study to measure the constructs of self-

566 determination, engagement, and learn- ing. Qualitative records of individual actions
567 (by the teacher and the students) could be made through observations in the classroom,
568 among other instruments (video records (e.g©. Shernoff et al. 2016); Experience
569 Sampling Method (e.g©. Zirkel, Garcia, and Murphy 2015)).

570 The study presented showed that the type and amount of teacher support can
571 moderate the association of self-determination with engagement and self-reported
572 learning. The data also showed that the amount of teaching scaffolding is conditioned
573 by the students' levels of self-determination. Therefore, future studies should use a
574 more experimental approach controlling the level of self-determination and including
575 scaffolding as a qualitative moderating factor in the different phases of the project.

576 **Disclosure statement**

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