

1 **TITLE:** FACTORS EXPLAINING STUDENTS' ENGAGEMENT AND SELF-
2 REPORTED OUTCOMES IN A PROJECT-BASED LEARNING CASE

3 **AUTHORS:** RAMÓN TIRADO-MORUETA^(a), YOLANDA CEADA GARRIDO^(b),
4 ANTONIO J BARRAGÁN PIÑA^(c), JUAN M. ENRIQUE GÓMEZ^(c) AND JOSÉ M.
5 ANDÚJAR MÁRQUEZ^(c)

6 **AFFILIATION:** ^(a)DEPARTMENT OF PEDAGOGY, UNIVERSITY OF HUELVA,
7 CAMPUS "EL CARMEN", HUELVA, SPAIN; ^(b)UNIVERSITY OF HUELVA, CAMPUS
8 "EL CARMEN", HUELVA SPAIN; ^(c)DEPARTMENT OF ELECTRONIC
9 ENGINEERING, COMPUTER SYSTEMS, AND AUTOMATIC CONTROL,
10 UNIVERSITY OF HUELVA, CAMPUS "EL CARMEN", HUELVA, SPAIN

11 **CONTACT:** rtirado@uhu.es, yolanda.ceada@sc.uhu.es, {antonio.barragan,
12 juanm.enrique, andujar}@diesia.uhu.es

13 **CORRESPONDING AUTHOR:** Ramón Tirado-Morueta

14

15 **ABSTRACT:**

16 Few Project-based learning (PBL) has been a methodology traditionally associated with
17 student engagement and good results. However, not all experiences are sufficiently
18 satisfactory. Comprehensive models that explain the success or failure of these
19 experiences are still lacking. The objective of this study was to understand the
20 mechanisms that explain student engagement and other satisfactory educational

21 results of PBL. During two academic years, the Sustainable Urban Race (SUR) project
22 was analyzed. In this project, students from secondary schools should design and build
23 an electric vehicle using solar energy. In the present study, a multigroup analysis of
24 structural equations was applied. The data showed a positive association of the
25 challenging and support-enriched context with the students' engagement, being
26 partially mediated by the satisfaction of the competence needs, peer relationships and
27 group autonomy. The study provides a useful framework for practitioners and
28 researchers of student engagement in PBL.

29 *Keywords: Engagement; learning environment; learning outcomes; Motivation; school*
30 *innovation*

31 **1. Introduction**

32 Project-based learning (PBL) makes students protagonists of learning (Stolk, 2009),
33 enabling them to gain crucial skills and knowledge (e.g. creativity, complex problem-
34 solving, meta-cognition, collaboration and communication) (Torrijo et al., 2021; Wu et
35 al., 2021). A fundamental characteristic of PBL is that it reflects real-world knowledge
36 acquisition, due to its emphasis on autonomy and learning in a collaborative and
37 inductive way, seeking answers, exploring different perspectives on a topic,
38 formulating and testing hypotheses or solving a problem (Prince & Felder, 2007). In
39 this format, teachers assume the role of guides, raising questions instead of giving
40 solutions (Bell, 2010).

41 The PBL approach could mean a student-centred environment with greater
42 engagement and motivation (Morais et al., 2021; Sukerti et al., 2018; Wang et al., 2022).
43 Research in the school environment has generally shown that students with a greater

44 sense of autonomy have better academic outcomes, such as perseverance, classroom
45 engagement, learning and achievement (e.g. Hardre & Reeve, 2003). However, PBL
46 does not always produce higher engagement and results. For example, a lack of expert
47 guidance and clear direction from the start can lead to confusion and frustration (Lee et
48 al., 2016), and unplanned implementation (Chen et al., 2021; Schaddelee & McConnell,
49 2018) can lead to missed goals. Although there are a multitude of studies that address
50 the reasons for the success of PBL, the findings present a messy picture and there are
51 few studies that comprehensively explain how student engagement in learning can be
52 stimulated through PBL.

53 In research on PBL, there are studies that have addressed this problem from various
54 points of view. Findings aligned with environmental complexity theory (Shernoff et al.,
55 2016) have shown the influence of teacher (Bédard et al., 2010) and peer support
56 (Barlow & Brown, 2020), and challenging tasks on student engagement and
57 performance (Morrison et al., 2020). Another series of studies has shown that the
58 concepts of self-determination theory (Deci & Ryan, 1985) can be a useful framework
59 for the analysis of the motiva- tions that cause students to engage in PBL (e.g. Koch et
60 al., 2016; Oh et al., 2020; Prigmore et al., 2016; Stolk, 2009).

61 The aim of this study is to provide a broader picture to better understand the factors
62 that stimulate student engage- ment in a PBL approach, which increases positive
63 learning (Pöysä et al., 2018; Torrijo et al., 2021). The results of this study will also be of
64 practical interest because they shed light on how teachers can stimulate students'
65 motivation and engagement in PBL. But it can also serve as a research framework from
66 which to delve into the various explanatory factors.

67 To study this mechanism, an adaptation of the Self-System Model of Motivational
68 Development (SSMMD) formulated by Skinner et al. (2008) was used, because it is a
69 framework in which the two main explanatory lines on engagement in PBL can be
70 integrated: (a) studies that emphasize a challenging and supportive environment; and
71 (b) studies that emphasize intrinsic motivation associated with student engagement
72 and outcomes. To check the validity of the research model, an analysis of the
73 invariance of the measure was carried out following the recommendations of Putnick
74 and Bornstein (2016), which is explained later.

75 Also, a learning context was implemented based on PBL and focused on environmental
76 sustainability. On the one hand, PBL is useful for building students' sustainability
77 expertise, particularly in terms of solution-oriented skills (Brundiers & Wiek, 2013). On
78 the other, environmental sustainability is the global objective that unites most coun-
79 tries. During two academic years, the methodological practices of the Sustainable
80 Urban Race (SUR) Project were analyzed. In the next sections the SUR Project and the
81 studies are described in detail.

82 **2. Theoretical framework**

83 To understand the mechanisms that explain student engagement and learning
84 outcomes in a project-based learning approach, the authors started with an adaptation
85 of the SSMMD (Skinner et al., 2008). The SSMMD focuses on engagement by describing
86 a broader motivational dynamic (Connell & Wellborn, 1991; Deci & Ryan, 1985) and
87 incorporates four principal higher order constructs: context learning; self; action; and
88 outcomes (see Figure 1).



90 Figure 1. Self-system model of motivational development (Skinner et al., 2008).

91

92 *2.1. Learning context*

93 The SSMMD maintains that engagement is greater in class- rooms (a) where
94 challenging, variable, meaningful and interesting assignments are offered, (b) with
95 teachers who support student’s autonomy and (c) have high expectations and provide
96 clear and consistent feedback to students (Jang et al., 2016; Skinner et al., 2008).

97 Based on previous research by Csikszentmihalyi and Schneider (2000), Shernoff (2013)
98 formulated the conceptual model of environmental complexity, arguing that optimal
99 learning contexts that promote student participation can be characterized by the
100 combination of environmental challenge and of environmental support. Decades ago,
101 Blumenfeld and Meece (1988) and Blumenfeld et al. (1992) observed higher levels of
102 cognitive participation in class- rooms where the teacher presented challenging tasks
103 and pressed for understanding. Students who perceive that teachers create a
104 supportive and well-structured learning environment, in which expectations are high,
105 clear and fair, are more likely to report engagement in school (Klem & Connell, 2004).

106 Environmental complexity is a construct that involves the simultaneous presence of
107 environmental challenge and environmental support (Shernoff et al., 2016). The
108 environmental challenge aims to guide the student’s action or thinking, and
109 environmental support helps them to achieve environ- mental challenges
110 (Csikszentmihalyi et al., 1993; Hektner & Asakawa, 2001; Newmann, 1992).

111 Environmental support refers to the instrumental, social and emotional resources made
112 available to help students meet environmental challenges (Reeve & Jang, 2006; Zhang
113 et al., 2009).

114 In studies focused on PBL, evidence has been found that supports the assumptions of
115 environmental complexity. A review of high-quality studies by Haughey and Raman
116 (2016) found that course rigor is one of the main determinants of engagement. In a
117 recent qualitative study, Morrison et al. (2020) showed the positive influence of a
118 challenging and teacher-supported context on student engagement and academic
119 performance. Likewise, in a PBL approach focused on the autonomy of the student, the
120 evidence tends to coincide in pointing out the importance of an expert orientation and
121 a clear direction from the beginning since this will avoid confusion and reduce the
122 stress produced by uncertainty, and thus help achieve goals (Bédard et al., 2012; Lee et
123 al., 2016). Studies such as Barlow and Brown (2020) have also shown the importance of
124 peer interactions in correlating with positive outcomes.

125 *2.2. Satisfied needs*

126 In the SSMMD, the developing person is viewed as an active partner in the
127 construction of the self-system from the first moments of life. The collection of
128 evaluation processes through which the person estimates his or her status with respect
129 to three basic psychological needs: competence, autonomy and relationship, and within
130 particular contexts is viewed as the self-system (Connell & Wellborn, 1991; p. 51). Each
131 of the three needs has been widely studied from the perspective of self-determination
132 theory (SDT) (Deci & Ryan, 1985). An important principle underlying this model is that
133 these three needs are experienced simultaneously (sometimes complementary and

134 sometimes in conflict), and they are part of a single dynamic system (Connell &
135 Wellborn, 1991; p. 70). 'Ideally, when the child is being optimally challenged on a task
136 that is meaningful and when others involved in the activity are perceived as
137 emotionally supportive, synergy -between the three needs- will occur resulting in
138 optimal engagement'.

139 In school contexts, a psychological well-being emerges that is relevant in the
140 motivation of students to become engaged with learning, since these three needs are
141 satisfied (Jang et al., 2012). Robust predictors of a student's effort and their emotional
142 responses to success and failure are appreciations of self-efficacy, academic
143 competence, and control (Elliot & Dweck, 2005). Evidence has also been found that has
144 shown that when the teacher meets these three needs, student engagement increases
145 (Cents-Boonstra et al., 2021).

146 SDT has been a widely used framework in research on participation in PBL
147 approaches. SDT is an appropriate analytical framework for PBL as it is based on a
148 student autonomy support approach (Stolk, 2009). Since students become key players
149 in completing their courses and high-level intrinsic and extrinsic motivation is
150 necessary (Oh et al., 2020), SDT can provide important insights into the motivational
151 processes that make students learn and progress. autonomously and commit to the
152 project. (Liu et al., 2009; Prigmore et al., 2016). For example, Koch et al. (2016) found
153 that basic psychological needs are significant predictors of academic engagement.
154 Other findings have found a mediation of internal motivation in the relationship of the
155 PBL context with learning outcomes (Orji & Ogbuanya, 2020).

156 However, there are few explicit studies (Albers & Johnson, 2016; Botella Nicolás &
157 Ramos Ramos, 2020) that analyze the relationships of each of the three psychological
158 needs with the different facets of engagement.

159 *2.3. Engagement and positive results*

160 There is a broad consensus among educational researchers to recognize the construct of
161 academic engagement as a determining factor for a student's success in school
162 (Fredricks et al., 2004; Nelson, 2016; Skinner et al., 2008). There is solid evidence that
163 shows that engagement predicts positive results in the tests and students' learning (e.g.
164 Jimerson et al., 2003).

165 The student's engagement is a construct that describes plastic aspects of conduct that
166 are beneficial for adaptation within the school context and learning. It works as a
167 project begun by the undergraduate toward the gaining of scholastic/educational goals
168 (Jang et al., 2012). It is a multifaceted construct that incorporates aspects that are
169 mutually reinforced and interconnected (Wang et al., 2016). Some review- ers have
170 suggested that it is useful to distinguish affective, behavioral and cognitive forms
171 (Christenson et al., 2012; Fredricks et al., 2004, 2016; Wang et al., 2016). Other empir-
172 ical studies have focused on the validation of these con- structs, including the
173 disengaged dimensions and their relationship with other facets of engagement (Hospel
174 et al., 2016). Other validation studies have found more pronounced differences
175 between the affective facet and the other facets of engagement (Ben-Eliyahu et al., 2018)
176 and positive relationships have been found between affective engagement and
177 cognitive-behavioral engagement of students (Pöysä et al., 2018).

178 Although there are no explicit studies in PBL research showing relationships between
179 different facets of engagement, numerous studies show a positive connection between
180 engagement and course success rate (Morais et al., 2021; Orji & Ogbuanya, 2020) and
181 other transversal skills. For example, focusing on student motivation and engagement,
182 Sukerti et al. (2018) studied PBL in essay writing and info- graphic design, improving
183 the participation of students working on various projects, obtaining an improvement in
184 the understanding of grammar and vocabulary during the review by peers, as well as
185 collaboration and communication skills as they progressed working in groups.
186 Likewise, a study by Torrijo et al. (2021) found a positive effect of motivation and
187 commitment on transversal skills such as teamwork, communication and critical
188 thinking.

189 Finally, although scarce, there are findings that have shown an explicit mediation of
190 cognitive engagement in the relationship between intrinsic motivation and the
191 acquisition of practical skills (Cheng, 2013).

192 **3. Hypotheses**

193 In order to establish a more orderly picture that helps to delve into the mechanism that
194 explains student participation and results in a PBL approach, the authors make the
195 following arguments.

196 The literature on motivation for learning, school climate and engagement suggests that
197 the learning environment promotes meaningful engagement when challenge and
198 environmental support are presented in combination (e.g. American Psychological
199 Association, 1997; Larson, 2011; Reeve et al., 2004; Zedan, 2010). These postulates have
200 been partially or totally corroborated in research on PBL. Both a review (Haughery &

201 Raman, 2016) and empirical studies (Barlow & Brown, 2020; Bédard et al., 2010; Lee et
202 al., 2016; Morrison et al., 2020) highlight that for students to participate in the project
203 and to have good results the courses must be rigorously designed. That is, in a PBL
204 context there must be a challenging task, expert guidance and support from the
205 beginning, and an atmosphere of peer cooperation. Considering these previous
206 findings, the first hypothesis formulated was the following:

207 H1. The students' perception that the project has been challenging (challenger) and
208 that they had the support to develop it (supports) will be positively correlated with (a)
209 affective and (b) cognitive engagement.

210 However, the SSMMD delves into the previous assumption and suggests that when
211 students are adequately challenged in a meaningful task and perceive cognitive and
212 emotional support from their teachers and peers, there will be a synergy that results in
213 an optimal engagement because the needs for autonomy, relationships and self-efficacy
214 have been satisfied (Connell & Wellborn, 1991; Skinner et al., 2008). In PBL contexts,
215 there is also evidence that has shown the mediating role of the satisfaction of the three
216 psychological needs in the relationship between the learning context and engagement
217 (Cents-Boonstra et al., 2021; Orji & Ogbuanya, 2020). Taking these premises into
218 account, the hypotheses that arise in this study were the following:

219 H2. The students' perception that the project has been chal- lenging (challenger) and
220 that they had the support to develop it (supports) will be positively correlated with the
221 satisfaction of their needs (i.e. for autonomy, relationship and self-efficacy).

222 Students' perception that their needs for (a) autonomy, (b) relationship and (c) self-
223 efficacy have been satisfied will be positively correlated with their affective (H3a, b, c)
224 and cognitive engagement (H4a, b, c) in learning tasks.

225 There are studies that have shown internal dynamics between the dimensions of
226 engagement (Skinner et al., 2008), showing that emotions feed behaviors in the
227 classroom. This evidence empirically reinforces the assumptions of theories such as
228 self-determination (Deci & Ryan, 1985) and the motivation of efficacy (Harter, 1978)
229 that suggest that it is emotions, such as interest and enthusiasm, which fuel engaged
230 behaviours such as effort and persistence. Although there is no explicit evidence in PBL
231 research for associations between cognitive and affective facets of engagement, the
232 authors drew on findings from a broader field and formulated the following
233 hypothesis:

234 H5. The degree of affective engagement of the students will be positively correlated
235 with the degree of cognitive engagement.

236 Students learn more if they are engaged cognitively (Schaddelee & McConnell, 2018).
237 Concentration has been related to depth of cognitive processing and academic per-
238 formance (Corno & Mandinach, 1983). Studies conducted in PBL contexts have shown
239 positive associations of cogni- tive engagement with the rate of hands-on learning
240 (Morais et al., 2021; Orji & Ogbuanya, 2020), as well as with increased transversal skills
241 (Sukerti et al., 2018; Torrijo et al., 2021). Taking into account this background, the sixth
242 hypothesis proposed in this study is the following:

243 H6. The degree of cognitive engagement will be positively cor- related with the
244 technical (H6a) and transversal learning (H6b).

245 Figure 2 shows the graphic representation of the hypotheses raised in the research.

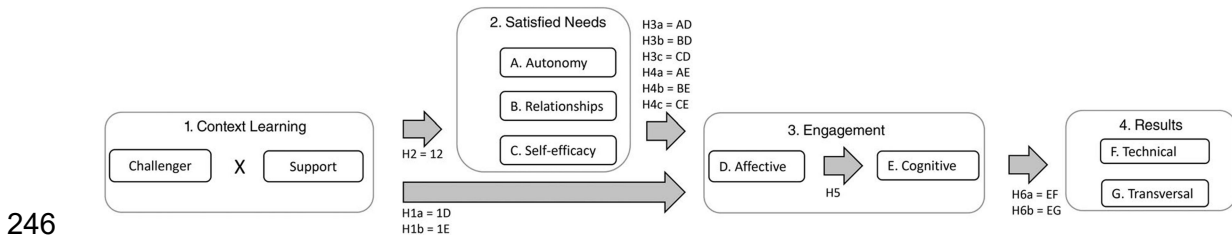


Figure 2. Hypotheses tested.

249

4. Method

4.1. Learning context

251 This study was based on an educational project that is targeted at secondary school
252 students, which is designed for to increase interest in technology and science, called
253 the SUR project. SUR is carried out in the south-west of Andalusia (Spain) and is
254 intended to promote scientific and technical careers among secondary school students,
255 while also trying to bring science, technology and innovation closer to society in
256 general. A network of secondary education schools participates in the SUR project, the
257 objective of which is to create a vehicle -using a simple technical set and recycled
258 materials- that allows at least one person to be transported in an urban setting. The
259 project concludes at the end of the academic year with a prototype race.

260 The project seeks to develop engineering skills and cross-sectional skills such as
261 creativity, collaboration, decision-making, work organization and time management,
262 among others. The relationship of the project staff with the schools was developed in
263 the following phases:

264 **Technical conferences.** Organized at the university pro- moting the project, they were
265 the first contact with the professors involved. The act involved the presentation of the
266 regulations, the tests to be carried out, evaluation criteria and the improvements
267 compared to previous editions. Finally, a series of training courses were presented to
268 update the knowledge of the participating teachers and support their task.

269 **Vehicle construction.** Participants in this phase must build a 3 or 4-wheel solar vehicle
270 capable of transporting one person. Furthermore, they must solve some proposed
271 technical challenges, such as building a telemetry system. This phase starts with the
272 visit of the project technicians to each secondary school to deliver a development kit
273 (engine, solar panels and components) and advise the teach- ers on the construction of
274 the vehicle.

275 From then to the date of the race, several visits to schools were made to assess the
276 development of each project. These visits were useful to solve problems with the
277 construction of the vehicle and with the use of Arduino, the program- ming platform.
278 The construction of the vehicle was incor- porated into the curriculum subjects in other
279 cases the project was approached as an extracurricular activity.

280 **Public competition.** At the end of the academic year, all the secondary schools
281 participated in this race with their prototypes. This took place at the campus of the
282 university of—hidden for review.

283 To configure the learning context, a series of organiza- tional measures were taken
284 based on the environmental complexity framework developed by Shernoff et al. (2016)
285 for the design of challenging and supportive environments (Table 1).

	Challenging and supportive learning environments (Shernoff et al., 2016)	Organizational measures
Challenger	Mastery of concepts, skills and/or literacies. Challenging, complex and situated tasks. Clear goals. Expectations and assessments for mastery.	The construction of the vehicle is adapted to the curriculum. Students must create a solar vehicle during the academic year. Vehicle must be capable of transporting at least one person in an urban environment. Several visits to the schools were made to assess the evolution of their projects.
Supports	Material support. Supportive relationships. Performance feedback. Active and 'hands-on' learning.	The organization provides the participating secondary school with a development kit. Support was provided for the teacher, students and staff. Project technicians visited schools to advise on the construction of the vehicle. Problems were solved with the construction of the vehicle and Arduino programming.

287

288

Table 1. Learning context. .

289 In schools, the project usually integrates several subjects (curricula) or is the practical
290 part of a subject.

291 The dynamic usually begins with the presentation of the project (e.g. 'At the beginning,
292 the project and the challenges are presented to the students and they begin by
293 contributing their own solutions and designs, and finally the most appropriate one is
294 chosen. Plans are drawn up for the construction and presentation of the project'—
295 teacher Gregorio). The characteristics and organization of a project are also usually
296 explained (e.g. 'we explain the dynamics of a project, the division of tasks into groups,
297 the parts that compose it are discussed, and how to deal with construction and possible
298 modifications'—teacher Sergio). According to the testimony of the teachers, the
299 students used the explanations given by the teachers and devoted themselves to the
300 assigned tasks and gave their opinion on the different sections of the project.

301 Normally, the work is directed by the teacher who divides the class group into
302 subgroups and assigns different functions to each one ('the teacher marks the work and
303 assigns roles depending on the characteristics and interests of each student'—teacher
304 Javier). The teachers usually guide during the project (e.g. 'my role in the project was
305 to direct and guide the organization of the project, as well as collaborate in the

306 contribution of solutions' – teacher Pepe), although the last decisions were taken by the
307 students. Figure 3 shows some images of SUR 2017–18 and 2018–19 in the construction
308 phases, prototype exhibition and in the race.



Designing the prototype



Testing components



Assembling components



Vehicle exhibition

309

310 Figure 3. Images of SUR project (in the construction phases, prototype exhibition and in the race).

311 4.2. Data collection and participants

312 The data collection was carried out in two academic years, 2017–18 and 2018–19. In
313 2017–18, 103 students from five secondary schools, aged between 14 and 19
314 participated, and 66% were male. In 2018–19, 62 students from ten secondary schools,
315 aged 14 to 19 years, participated and 84% were male.

316 Data collection procedure was as follows: in the first phase of the project teachers were
317 taught about the objectives of the study. The measuring instrument was provided to

318 the participants on the day of the race. Participation in the study was voluntary and
 319 anonymity was guaranteed.

320 *4.3. Measurement*

321 Students' perceptions of context learning, satisfied needs, engagement and learning
 322 outcomes were assessed with individual student reports about the project and their
 323 interactions with teachers, classmates and staff. However, for the measurement of the
 324 learning context, semi-structured interviews were previously carried out with all the
 325 teachers participating in the project, based on the categories of the model formulated
 326 by Shernoff et al. (2016). This model was a composite of an Environmental Challenge
 327 Scale ($\alpha=.66$) and Environmental Support Scale ($\alpha=.70$) that showed the predictive
 328 validity of both measures together on students' engagement.

329 For the coding of the interviews, the software Altas ti 22 was used. The variables that
 330 saturated the responses related to the challenging aspects and the supports of the
 331 project were obtained. These variables made up the items of the scales used to measure
 332 the challenging and supportive aspects in the learning context (Table 2).

Challenging and supportive learning environments		Example
Challenger	The project was clearly outlined	'The main attraction, from my point of view, is the possibility of applying the knowledge learned in the subject of technology to the construction of something tangible' (Carmen)
	The project was realistic	'They leave the routine of theory and see their ideas materialize in a practical way ...' (Pepe)
	The project was challenging	'They like the project, the construction of something created by them or that they have collaborated with and that compete with other institutes or the university.' (Jonathan)
Supports	Tools and systems used to organize work	'We had little means, all the material was recycled, bicycles from the garbage, wheels from the junkyard and the electronics of the printers and the occasional Arduino kit' (Bernard)
	Relationship with peers	'... A real sense of group is created, they feel that they share something that represents them, they work as one' (Gregorio)
	Relationship with the teachers	'Participation is attractive, especially because of collaborative work between students and teachers in which we are all the same' (Pepe)
	Advice/guidance given by the staff	'We have always had the support of the group that organizes the SUR Project. For more technical constructions they helped us from outside with welding or from the university' (Sergio)
	Experience as a team	'... no matter how small the participation of a student in the construction of the vehicle may be, they feel that they have done it' (Javier)

333

334

Table 2. Codes extracted from teacher interviews.

335

336 As a result of the qualitative inquiry process, the follow- ing constructs were obtained,
337 which were answered with a 4-point Likert scale from 1 - 'not at all true' to 4 -
338 'completely true':

339 a. Challenger (CH) refers to the perception of the struc- ture, i.e. the clarity,
340 realism and challenge involved in carrying out the project. The scale
341 developed showed good reliability in 2017–18 and reliability was low in
342 2018–19 ($\alpha=.83$ and $.50$, respectively). It comprised three items: 'the project
343 was clearly outlined'; 'the project was realistic'; and 'the project was
344 challenging'.

345 b. Support (SU) refers to the satisfaction with the amount of guidance received
346 by teachers and staff, as well as with the supportive relationships among all
347 participants in the project. The scale showed opti- mal reliability in 2017–18
348 and 2018–19 ($\alpha=.94$ and $.91$, respectively) and comprised of five items, such
349 as 'how satisfied have you felt with': '... tools and systems used to organize
350 work?'; '... advice/guidance given by the faculty?'; '... the relationship with
351 team members?', and '... good relationship with the teaching staff?'

352 With respect to satisfied needs, the research model was composed of three constructs
353 (Deci & Ryan, 1985):

354 a. Autonomy (AU) notes the level of autonomy per- formed by students in
355 their classroom through an adaptation of the scale used by Ruzek et al.
356 (2016) with $\alpha = .70/.80$. The predictive validity of this measure with observed
357 student participation and self-reported student participation has been
358 demonstrated by previous research (Hafen et al., 2012). The scale for this

359 project had moderate reliability in 2017–18 and 2018–19 ($\alpha=.65$ and $.66$,
360 respectively) and was comprised of items such as ‘we made decisions on
361 how to develop it’; ‘we decided how to carry out group activities’; and ‘we
362 had very stimulating discussions’. For the answers, a 4-point Likert scale
363 was used from 1 - ‘not at all true’ to 4 - ‘very true’.

364 b. Relationship (RE) refers to the need that people have to feel that they belong
365 to a particular project via a scale designed and proven by Mikami et al.
366 (2005) and recently used by Ruzek et al. (2016), showing the predictive
367 validity of the measure on behavioral engagement reported by students.
368 The scale developed showed acceptable reliability in 2017–18 and 2018–19
369 ($\alpha=.74$ and $.69$, respectively). The scale used contained three items: ‘how
370 many colleagues from the team respected and listened to your opinions?’;
371 how many teammates ignored your opinions?’; and ‘with how many
372 colleagues from the project did you get along?’. Student replies were
373 collected through a 5-point Likert scale from 1 - ‘everybody’ to 5 - ‘nobody’.

374 c. Self-Efficacy (SEL) referring to the need of human beings to feel competent
375 in their interactions with the environment through a 3-item scale drawn
376 from the Patterns of Adaptive Learning Survey’s academic efficacy measure
377 (Midgley et al., 2000), with responses on a 4-point Likert scale from 1 - ‘not
378 at all true’ to 4 - ‘very true’. The scale had good accuracy in 2017–18 and
379 2018–19 ($\alpha=.86$ and $.79$, respectively). The scale used had three items: ‘while
380 carrying out the project:’ ‘...I felt that I could perform all the tasks that were
381 proposed to me’; ‘...I have been sure that I mastered all the contents of the
382 project’; and ‘...I thought I did it well even in the most difficult tasks’.

383 Engagement refers to a meta-construct that comprises various dimensions of attraction
384 or participation in school (Fredricks et al., 2004, 2016). To evaluate this
385 multidimensional construct, the four subscales validated by Fredricks et al. (2016) were
386 utilized. The dimensions evaluated were: affective engagement (AE) ($\alpha=.88$ in 2017–18;
387 $\alpha=.81$ in 2018-19) (e.g. 'I liked participating in the project', and 'I enjoyed learning new
388 things'), and cognitive engagement (CE) ($\alpha=.83$ in 2017–18; $\alpha=.89$ in 2018–19) (e.g. 'I
389 reviewed the work to see what was good', 'I thought about the different ways to solve
390 a task', and 'I tried to learn from my mistakes when something did not go well'). For
391 the answers, a 4-point Likert scale was used (1= not at all true to 4 = very true).

392 In order to verify the learning outcomes, reports from students were used. Two ad hoc
393 scales were used and responses were on a 4-point Likert scale from 1 - 'not at all true'
394 to 4 - 'very true':

395 a. Technical Learning (TEL) refers to the learning of technical skills within the
396 project. The scale proved to be reliable in 2017–18 ($\alpha=.86$) and 2018–19
397 ($\alpha=.75$). Items such as 'I have learned to design and build a vehicle, capable
398 of transporting a person, without breaking', 'I manage mechanical design
399 programs', 'I design and build simple electronic circuits', and 'I apply basic
400 programming principles through the ARDUINO platform' were used to
401 measure TEL.

402 b. Transversal Learning (TRL) refers to the generation of common
403 competences such as communication, teamwork, leadership, etc. (Frank et
404 al., 2003). The scale showed good reliability in 2017–18 ($\alpha=.86$) and 2018–19
405 ($\alpha=.86$). Items such as 'through this project I have learned to:' '... help

406 preserve the environ- ment’; ‘... carry out original projects’; and ‘... write
407 projects’ were used.

408 In order to verify the validity of the constructs (CH, SU, AU, RE, SEL, AE, CE, TEL and
409 TRL), other indicators of convergent validity and discriminant validity were tested. On
410 the one hand, the one-dimensional analysis showed that only the value of the first
411 component, for all the constructs was > 1 . A re-specification of the original scales was
412 per- formed, eliminating variables with factor loads that did not exceed the minimum
413 required value of 0.50. Thus, the AU scale was modified and lost one item in 2018–19,
414 and RE scale lost one item in 2017–18.

415 To measure convergent and discriminant validity, other indicators were used, such as
416 the average variance extracted (AVE) and the square root of the variance. The AVE of
417 the constructs was above the thresholds of 0.53 (except the autonomy construct in both
418 academic years; .47 and .50) and the internal consistency criteria were complied. On the
419 other hand, the discriminant validity criterion was fulfilled since the square roots of the
420 AVE of each construct were greater than their correlations with other constructs.

421 Further details of the scales are provided in Appendix A and B, including the factor
422 load of each item, Cronbach’s alpha, AVE, and the discriminant validity analysis.

423 *4.4. Data analysis*

424 The hypotheses were tested using structural equation modeling (SEM) with AMOS
425 software (Figure 2). According to this method, each theory consists of a group of
426 correlations, and if the theory is valid, the correlation patterns (assumptions) can be
427 reproduced in empirical data (Byrne, 2013).

428 Simultaneously analyzing all the variables and their relationships, the SEM statistically
429 tests the theoretical model analyzed, to verify the consistency of the proposed model
430 with the data. The model supports the plausibility of the relationships presented, if the
431 goodness of fit is adequate; however, if it is not adequate, the plausibility of the model
432 is rejected. The usual indices of the three fit categories of the model were used to
433 measure the goodness of fit of the model (Hair et al., 2006; absolute, parsimonious and
434 incremental).

435 Following the recommendations of Hair et al. (2006), the following adjustment criteria
436 were established: for N observed variables ≤ 12 and $N < 250$. The root means square
437 error of approximation (RMSEA) was used ($0 < \text{RMSEA} < 0.08$). For the incremental
438 measurement of fit, the Incremental Fit Index (IFI) and comparative fit index (CFI)
439 were used ($0.97 < \text{IFI} < 1$; $0.97 < \text{CFI} < 1$). Lastly, for the measurement of parsimonious
440 fit, the normed χ^2 (χ^2/df) was used ($1 < \chi^2/\text{df} < 2$).

441 A multigroup analysis was performed to test the invari- ance (equivalence) of the
442 model for data from 2017–18 and 2018–19. Measurement invariance refers to the degree
443 to which the parameters of the measurement model are similar in both academic years
444 (2017–18 and 2018–19) and was evaluated in three levels (Putnick & Bornstein, 2016):
445 mea- surements model (invariance of factorial loads of latent variables); intercepts
446 model (invariance of intercepts); and structural model (invariance of structural
447 weights).

448 To analyze the invariance, the tests recommended by Byrne (2013) were used, starting
449 from the determination of a good fit of the multigroup configurational model. This
450 model will serve as the basis to analyze the remaining, more restrictive models.

451 Previous research studies reflect the use of the chi-square difference ($\Delta\chi^2$) test to
 452 compare restrictive models. However, given the sensitivity of χ^2 to sample size and
 453 non-normality (Hair et al., 2006). Cheung and Rensvold (2002) proposed the increase in
 454 CFI (ΔCFI), to determine whether the compared models are equivalent. In this sense,
 455 when the difference between the CFI of the two models is greater than 0.01, the less
 456 restrictive restricted model is accepted and the other rejected.

457 5. Results

458 To verify the assumption of normality of the variables used in the structural equation
 459 model, a statistical analysis was performed. In addition, asymmetry and kurtosis
 460 analyses were performed (see Table 3). These analyses, according to Curran et al.
 461 (1996), establish the limits, in absolute values, until the behavior can be considered
 462 close to normality, for values between 7 for kurtosis and 2 for asymmetry. The
 463 normality condition was accepted, since the results showed that the values of both
 464 statistical tests complied with this rule.

	Study 2017-18							Study 2018-19						
	N	Mean	SD	Asy	Kurt	Min	Max	N	Mean	SD	Asy	Kurt	Min	Max
Challenger	103	3.28	.89	-1.24	.77	1	4	62	3.32	.46	.13	-1.05	2.3	4
Support	103	3.34	.76	-1.81	3.33	1	4	62	3.34	.80	-1.84	2.92	1	4
Autonomy	103	3.26	.48	.04	-.97	2.2	4	62	3.12	.48	-.03	-.29	2	4
Relationship	103	3.04	.52	-.04	1.91	1	4	62	2.89	.40	.43	1.56	2	4
Self-efficacy	103	2.99	.76	-.19	-1.02	1.3	4	62	3.22	.56	.04	-.86	2	4
Affective engagement	103	3.62	.51	-1.29	1.18	2	4	62	3.67	.43	-.84	-.92	2.8	4
Cognitive engagement	103	3.37	.55	-.72	.96	1	4	62	3.34	.62	-.43	-.79	1.8	4
Technical learning	103	2.85	.72	-.48	.32	1	4	62	3.13	.55	.01	-.48	1.8	4
Transversal learning	103	3.12	.55	-.70	1.24	1	4	62	3.38	.53	-.77	.52	1.7	4

465

466 Table 3. Descriptive results of the constructs.

467 The self-reported descriptive results in both editions were similar. It is worth noting
 468 the high average score of affective engagement stands out over the rest of the variables.
 469 Likewise, the data show that the students were satisfied with the support received
 470 during the project and perceived the challenging experience in both editions.

471 5.1. Multigroup structural model

472 After testing the causal structure of each model, the param- eters that were not
 473 significant in any of the editions were eliminated until reaching optimal fit indices: (a)
 474 including technical learning ($\chi^2/df = 1.62$; RMSEA = 0.05 (90% con- fidence interval
 475 [CI] = 0.02, 0.10); IFI = 0.96 and CFI = 0.96); and (b) including transversal learning
 476 ($\chi^2/df = 1.34$; RMSEA = 0.04 (90% confidence interval [CI] = 0.00, 0.08); IFI = 0.98 and
 477 CFI = 0.98).

478 5.1.1. Review of the hypotheses

	Study 2017–18		Study 2018–19	
	Direct effects (β)	Indirect effects (β)	Direct effects (β)	Indirect effects (β)
H1a. Challenger x Support → Affective engagement	.19*	.07*	.29*	.06*
H1b. Challenger x Support → Cognitive engagement	n.s.	.21**	n.s.	.24***
H2. Challenger x Support → Satisfied needs	.24**		.21**	
H3a. Autonomy → Affective engagement	.15*		.23*	
H3b. Relationships → Affective engagement	.31***		.12	
H3c. Self-efficacy → Affective engagement	n.s.		n.s.	
H4a. Autonomy → Cognitive engagement	.26***	.07**	.18*	.10*
H4b. Relationships → Cognitive engagement	n.s.	.15**	n.s.	.06
H4c. Self-efficacy → Cognitive engagement	.23**		.38***	
H5. Affective engagement → Cognitive engagement	.47***		.44***	
H6a. Cognitive engagement → Technical learning	.36***		.53***	
H6b. Cognitive engagement → Transversal learning	.43***		.56***	
Satisfied needs → Affective engagement		.31**		.28**
Satisfied needs → Cognitive engagement		.50**		.52**
Challenger x Support → Technical learning		.08**		.13***
Challenger x Support → Transversal learning		.09**		.13***
Affective engagement → Technical learning		.17***		.24***
Affective engagement → Transversal learning		.21***		.25***
χ^2/df (p)	1.62 (.033) / 1.34 (.128)			
CFI	.96 / .98			
IFI	.96 / .98			
RMSEA	.05 (.02-.10) / .04 (.00-.08)			

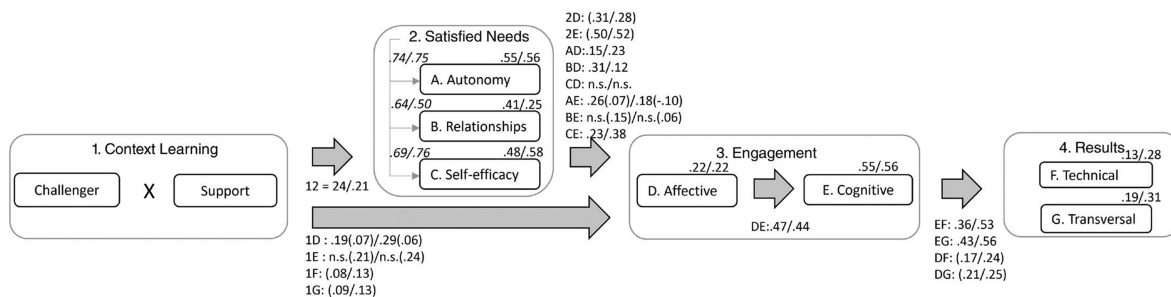
479 * $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$.

480 Table 4. Hypotheses, indirect effects and fit of the multigroup model.

481 Table 4 shows the indirect effects that indicate the effect of a determinant variable on
 482 another one, through its effect on other variables that intervene in the model. Indirect
 483 effects analysis can provide new information needed for a more detailed
 484 understanding of the relationships between the variables in the model. Figure 4 also
 485 shows the explained variances for each academic year (2017–18 and 2018–19) and the

486 coefficients that appear between the constructs, which represent the effect of a single
 487 determinant variable over one that is endogenous.

488



489

490 Figure 4. Structure of the model (direct effects) across 2017–18 and 2018–19 studies. Notes: (a) Values on
 491 the left indicate 2017–18 and values on the right correspond to 2018–19 coefficients. (b) Data in italics
 492 indicate the factorial loads of the variables autonomy, relationships and self-efficacy in the latent variable
 493 ‘satisfied needs’ during the 2017–18 and 2018–19 editions. (c) Numbers in parentheses indicate indirect
 494 effects.

495 Regarding the learning context, the data showed a significant and direct association of
 496 the challenge variable moderated by supports with the satisfaction of needs (H2) for
 497 autonomy, relationship and self-efficacy, both in 2017–18 ($\beta = .24$, $p < .01$) and 2018–19
 498 ($\beta = .21$, $p < .01$). Likewise, a challenging and supportive learning context showed a direct
 499 association with affective engagement in both editions. (H1a) (2017–18: $\beta = .19$, $p < .05$;
 500 2018–19: $\beta = .29$, $p < .05$). The indirect effects analysis revealed a partial mediation of the
 501 satisfaction of needs in the relationship of the learning context with affective
 502 engagement (2017–18: $\beta = .07$, $p < .05$; 2018–19: $\beta = .06$, $p < .05$).

503 Although the data did not show a direct association of the learning context with
 504 cognitive engagement (H1b), they did show a significant indirect association (2017–18:
 505 $\beta = .21$, $p < .01$; 2018–19: $\beta = .24$, $p < .001$). Therefore, the relationship of the learning context

506 with cognitive engagement was mediated by the satisfaction of the student's needs and
507 by its relationship with affective engagement.

508 Regarding the needs satisfied, an association of the variable autonomy with affective
509 engagement (H3a) (2017–18: $\beta=.15$, $p<.05$; 2018–19: $\beta=.23$, $p<.05$) was obtained in both
510 studies. Likewise, the association of autonomy satisfaction with cognitive engagement
511 (H4a) was direct (2017–18: $\beta=.26$, $p<.001$; 2018–19: $\beta=.18$, $p<.05$) but also indirect (2017–
512 18: $\beta=.07$, $p<.01$; 2018–19: $\beta=.10$, $p<.05$) partially mediated by affective engagement.

513 Also, the relationship variable was positively associated with the affective engagement
514 variable (H3b) (2017–18: $\beta=.31$, $p<.001$; 2018–19: $\beta=.12$, $\geq.05$) but not with cognitive
515 engagement (H4b). However, the data showed an indirect relationship between the
516 relationship between peers and cognitive engagement (2017–18: $\beta=.15$, $p<.01$; 2018–19:
517 $\beta=.06$, $\geq.05$) mediated by its relationship with affective engagement.

518 Regarding the self-efficacy, it did not show a significant relationship with affective
519 engagement (H3c) but was positively associated with cognitive engagement (H4c)
520 (2017–18: $\beta=.23$, $p<.01$; 2018–19: $\beta=.38$, $p<.001$). However, there were indirect effects of
521 the latent variable needs satisfied on affective engagement (2017–18: $\beta=.31$, $p<.01$; 2018–
522 19: $\beta=.28$, $p<.001$), therefore, it cannot be concluded that self-efficacy does not affect
523 affective engagement. Regarding the relationship between both dimensions of
524 engagement, a strong positive and significant association between affective and
525 cognitive engagement in both academic years stands out (H5) (2017–18: $\beta=.47$, $p<.001$;
526 2018–19: $\beta=.44$, $p<.001$), and an indirect association was found between affective
527 engagement and technical (2017–18: $\beta=.17$, $p<.001$; 2018–19: $\beta=.24$, $p<.001$) and
528 transversal learning (2017–18: $\beta=.21$, $p<.001$; 2018–19: $\beta=.25$, $p<.001$). Likewise, a strong

529 significant association of cognitive engagement with technical (H6a) (2017–18: $\beta=.36$,
 530 $p<.001$; 2018–19: $\beta=.53$, $p<.001$) and transversal learning (H6b) (2017–18: $\beta=.43$, $p<.001$;
 531 2018–19: $\beta=.56$, $p<.001$) was also found. Therefore, the data suggest that the association
 532 between affective engagement and student self-reported learning outcomes was
 533 mediated by cognitive engagement.

534 Lastly, the data also showed, in both studies, an indirect association of the perception
 535 of challenge toward the project moderated by the support received by the students
 536 with technical (2017–18: $\beta=.08$, $p<.01$; 2018–19: $\beta=.13$, $p<.001$) and transversal learning
 537 (2017-18: $\beta=.09$, $p<.01$; 2018-19: $\beta=.13$, $p<.001$).

	χ^2 (df)	$\Delta \chi^2$	p ($\Delta \chi^2$)	RMSEA (90% CI)	CFI	Δ CFI
<i>Technical learning</i>						
Configural model	35.98 (22)			.06 (.02-.10)	.957	
Measurement model	41.81 (24)	5.82	.05	.06 (.03-.10)	.945	.012
Intercepts model	39.84 (25)	3.85	.29	.06 (.02-.09)	.954	.002
Structural model	43.25 (28)	7.26	.29	.05 (.02-.09)	.953	.004
<i>Transversal learning</i>						
Configural model	29.68 (22)			.05 (.00-.08)	.977	
Measurement model	35.50 (24)	5.82	.05	.05 (.00-.09)	.965	.012
Intercepts model	33.29 (25)	3.61	.30	.04 (.00-.08)	.975	.002
Structural model	37.09 (28)	7.41	.28	.04 (.00-.08)	.972	.005

538

539 Table 5. Measurement invariance tests across 2017–18 and 2018–19 studies.

540 Finally, the invariance test across both years was performed (Table 5). In the model that
 541 includes technical learning, values of p ($\Delta \chi^2$) in the restrictive models (intercepts
 542 model and structural model) were not significant. Moreover, there was no significant
 543 deterioration in the CFI value with respect to the configural model
 544 (Δ CFI_{Intercepts}=0.002; Δ CFI_{Structural}=0.004). Also, in the model that includes
 545 transversal learning, values of p ($\Delta \chi^2$) in the intercepts model and structural model
 546 were not significant (Δ CFI_{Intercepts}=0.002; Δ CFI_{Structural}=0.005). Therefore, these

547 data show the invariance of the model between the measures carried out in 2017–18
548 and 2018–19, and with different groups of students and schools.

549 **6. Discussion**

550 In order to get a broader picture of the mechanisms that explain student engagement
551 and success in a PBL context, the authors used an adaptation of the SSMMD. In
552 general, SSMMD postulates that to the extent that the learning con- text meets the
553 needs (autonomy, relationship and self-efficacy) of the students, their activity and
554 performance will increase. In addition, by analyzing the invariance of the model, its
555 validity was shown throughout the academic year (2017–18 and 2018–19). Although the
556 analysis of the model has provided a more orderly idea of the findings of the PBL
557 research, it also proposes ways in which the research must continue in depth.

558 Regarding a challenging and supportive learning environment in PBL, the project
559 analyzed carefully followed the recommendations of Shernoff et al. (2016) and the
560 results showed that the learning context based on the challenge of developing a vehicle
561 through solar energy and winning the competition among multiple school projects was
562 very clear, realistic and challenging for the students. Likewise, in the Sustainable
563 Urban Race (SUR) project the students felt very supported by the material resources,
564 the staff, teachers and classmates. In tune with this perception of the context, the
565 students declared a high degree of affective engagement. Similarly, the teachers stated
566 that the project was a stimulating experience for the students due to the challenging
567 and practical nature of the task in a context endowed with supports to collaborate and
568 learn autonomously.

569 Likewise, according to the perceptions of students and teachers, the implementation of
570 the project presented in this study is adjusted to the conditions of the PBL (Chen et al.,
571 2021). These findings provide further insight into how students can be more engaged
572 in PBL contexts where student engagement and motivation are sought (Schaddelee &
573 McConnell, 2018).

574 Regarding the association of learning context with satisfied needs, data from the
575 current study, consistent with previous findings, have shown that if the project is
576 challenging and if it offers the necessary supports—materials, teachers and
577 colleagues—(Shernoff et al., 2016) the autonomy needs (Lee et al., 2016), relationship
578 (Zhang et al., 2018) and self-efficacy (Shernoff et al., 2016) will be achieved. The
579 analysis showed a direct relationship between the challenging context and, at the same
580 time supported by teachers with high levels of autonomy, the relationship with peers
581 and self-efficacy. These results are consistent with other findings that underscore the
582 importance of clear and expert guidance and direction to avoid confusion and frus-
583 tration in a learning environment, based on student autonomy and improving student
584 self-efficacy (Lee et al., 2016). Although, taking the SDT as a reference, it would be con-
585 venient to delve into the nature of the projects (heuristic rather than algorithmic) and
586 the scaffolding measures to manage time and organize learning practices (Bédard et al.,
587 2012; Stolk, 2009).

588 Regarding the association of satisfied needs with engagement, the use of the SDT (Deci
589 & Ryan, 1985) has been recurrent in explaining student engagement and performance.
590 The data from this study are further evidence that the SDT is a framework that can
591 provide interesting information to understand motivational processes in PBL (Albers

592 & Johnson, 2016; Liu et al., 2009; Oh et al., 2020; Prigmore et al., 2016). The results
593 partially coincide with other findings that showed that basic psychological needs are
594 significant predictors of academic engagement (Botella Nicolás & Ramos Ramos, 2020;
595 Koch et al., 2016). However, studies focused on PBL that used the SDT to explain
596 student engagement yield confusing results by not differentiating the facets of
597 engagement in their analyses (Botella Nicolás & Ramos Ramos, 2020; Jaeger & Adair,
598 2018).

599 The current analysis showed that the relationship between satisfied needs (self) and
600 engagement is complex. So far the detailed nature of the relationship between the two
601 meta-constructs is not clear (Ruzek et al., 2016). In this study, the results of the
602 structural model showed that the affective facet of engagement is associated with the
603 needs of autonomy and relationship with peers, while the cognitive facet is directly
604 associated with the autonomy and perception of competence of the students (Jaeger &
605 Adair, 2018; Makkonen et al., 2021) and indirectly with peer relationships. That is to
606 say, the data suggest that students become cognitively involved with the project if they
607 feel capable of carrying it out successfully and they also perceive that they have
608 autonomy to adjust it to their interests. Although apparently peer relationships were
609 not associated with cognitive engagement, the analysis showed an indirect effect
610 through its relationship with affective engagement. Likewise, although there was no
611 apparent relationship between students' self-efficacy and affective engagement, the
612 indirect effects of the latent variable (i.e. satisfied needs) suggest a deeper analysis of
613 the relationship between both variables. In addition, the results were added to other
614 evidences that showed that affective engagement is the greatest contributor to the

615 internal dynamics of engagement, reinforcing cognitive participation (Skinner et al.,
616 2008). The main determinant of students' cognitive engagement was affective
617 engagement (i.e. that the project is pleasant and enjoyed by students) and for this it is
618 necessary that students perceive autonomy and a good cooperative work climate.
619 Therefore, these results suggest that the organization of the project and the definition
620 of teacher roles should be aimed at creating an affective learning climate and
621 providing students with the material and cognitive resources that allow them to carry
622 out the project autonomously (Stolk, 2009).

623 Regarding the association of learning context with engagement, data also showed a
624 direct relationship of a challenging enriched and supportive environment with the
625 affective facet of engagement and partially mediated by the satisfaction of the needs of
626 autonomy, relationship and self-efficacy (Ruzek et al., 2016).

627 On the one hand, these results suggest that when the goals of the project are clear and
628 challenging, and the necessary material and social supports are provided, students will
629 have a greater opportunity to enjoy and become involved in the learning process.
630 Although there are few studies focused on PBL that have considered the various facets
631 of engagement in their analyses, their results suggest a direct relationship between the
632 challenging and strongly supported environment and the affective facet of engagement
633 by avoiding stress and confusion (e.g. Bédard et al., 2010; Lee et al., 2016).

634 In addition, although there is evidence of the mediating role of intrinsic motivation in
635 the relationship between the PBL context and engagement (Orji & Ogbuanya, 2020),
636 these results specify that part of the influence of the learning context on affective

637 engagement is due to its ability to enhance student self-efficacy and provide supports
638 for autonomous and collaborative learning with their peers.

639 Although there was no direct relationship between learning context and cognitive
640 engagement, indirect effects analysis showed that affective engagement acted as a
641 mediator. In tune with the assumptions as the motivation of efficacy (Harter, 1978), the
642 results suggest that the learning context acted as a facilitator of pleasant emotions that
643 acted as a stimulus so that students become cognitively involved with the learning
644 task.

645 Finally, it is worth noting the indirect association of the learning context, which
646 combines a challenging and significant task with the necessary material and human
647 supports—with the learning outcomes mediated by the satisfaction of needs and by
648 their relationship with positive emotions. These results corroborate other findings that
649 show the effectiveness of PBL as long as the context facilitates intrinsic motivation and
650 student participation (Orji & Ogbuanya, 2020).

651 Regarding the association of engagement with results, as evidenced by previous
652 studies (Corno & Mandinach, 1983; Kelly, 2008; Schaddelee & McConnell, 2018; Sirin &
653 Rogers-Sirin, 2004), the results showed a strong direct relationship between the
654 students' cognitive effort and both technical learning (Li et al., 2020; Umar & Ko, 2022)
655 and with transversal skills (Torrijo et al., 2021). However, in line with approaches to
656 self-determination and efficacy motivation, it is worth noting the importance of
657 positive emotions (e.g. enjoying, feeling good). The data showed an indirect association
658 of affective engagement with outcomes (both technical and transversal) mediated by
659 cognitive engagement (Cheng, 2013); that is, positive emotions (affective engagement)

660 were a stimulus for students' cognitive processing that led to favorable self-reported
661 results.

662 **7. Practical implications**

663 This study suggests an organization of learning context that poses a challenging project
664 for the students, and at the same time provides the necessary supports for them to
665 carry out the project with self-determination. On the one hand, for students to be
666 involved in PBL, it is essential for them to perceive the project as interesting and
667 valuable, but also to cope with some of the social difficulties associated with working
668 in small groups, students need time and support (Schaddelee & McConnell, 2018). On
669 the other hand, students need to have autonomy as independent thinkers (Zhang et al.,
670 2018), and need to have autonomy, collaborating and sharing goals with peers
671 (Kokotsaki et al., 2016). To do so, they need to feel that they have the necessary
672 competences to complete the project (Blumenfeld et al., 1992; Lee et al., 2016).
673 Therefore, teachers should make a timely and accurate evaluation of student feedback
674 to strengthen student thinking progresses and arouse their engagement in problem-
675 solving (Zhang et al., 2018).

676 In summary, the data reinforce the idea that affection and enjoyment while students
677 carry out the learning task is a central factor that acts as driver of a cognitive effort that
678 leads directly to favorable results. Therefore, teachers must be aware of the relevance of
679 positive emotions during the learning process and use the necessary measures to
680 promote them. In this sense, it is advisable to propose meaningful and challenging
681 tasks for students while managing technical and human supports that facilitate
682 autonomous and collaborative learning.

683 **8. Limitations and future studies**

684 Some limitations should be considered for future research. First, regarding the
685 measurement of learning context, perceptions of teachers and students are insufficient,
686 and other observation techniques of learning context should be used that provide
687 robustness to the results. For example, the Experience Sampling Method, based on the
688 subjective measure of experience during instruction (e.g. Zirkel et al., 2015), as well as
689 the coding of observation records of class- room activity (e.g. Shernoff et al., 2016).

690 Likewise, the transversal and technical learning was measured with self-reports, and
691 the use of objective measures such as skills and knowledge tests for technical learning
692 and classroom observations for cross-sectional learning is recommended. In second
693 place, the low reliability in the Challenger scale in the second study suggests the use of
694 broader response scales that increase the discrimination capacity of the respondents'
695 response. In third place, the study presents a general research framework which
696 should be further developed. For example, although the study has shown the synergy
697 between the processes of the self-system (competence, relationships and autonomy), it
698 is necessary to delve deeper into aspects of the context, such as the support of the
699 teacher in critical phases of the project and in the relationships of mutual support
700 between peers. Fourth, to further improve the validation of the model, multi-group
701 analyses could be carried out focused on curricular aspects, such as subjects,
702 educational stages or student groupings.

703 Lastly, it is necessary to delve deeper into the internal dynamics of engagement
704 (cognitive, affective and social) and its relationship with performance.

705 **9. Conclusions**

706 Although there is evidence of the factors that determine student engagement and
707 learning outcomes in PBL, there is a lack of studies that link them together, offering a
708 comprehensive vision for researchers and practitioners. This study used an adaptation
709 of the SSMMD and the environmental complexity construct to validate a
710 comprehensive framework that shows the mechanisms that explain the improvement
711 of student engagement and outcomes learning.

712 Using multi-group analysis with structural equations, this study has shown that a
713 challenging and supportive learning environment is directly associated with affective
714 engagement but will also influence cognitive engagement and learning outcomes to the
715 extent that autonomous teamwork is encouraged, and students feel empowered to
716 carry out the project successfully.

717 The data for this research come from the analysis of the project—hidden for review and
718 was obtained during two successive academic years. Fifteen groups of secondary
719 school students participated in this project with the aim of building an electric vehicle
720 using solar energy. The studies presented showed the challenging and supported
721 character of the SUR project and its positive effect on motivation and self-reported
722 learning by students.

723 In summary, this study provides a comprehensive approach to developing and
724 evaluating PBL experiences by providing inputs that can help teachers and educational
725 administrators organize and optimize educational experiences. But it also provides a
726 more orderly picture of the mechanisms that explain the students' engagement in PBL,
727 which is useful for research.

728

729 **Disclosure statement**

730 No potential conflict of interest was reported by the author(s).

731 **Funding**

732 This work was supported by the Fundación Española para la Ciencia y la Tecnología
733 (FECYT) [FCT-19-14492 and FCT-20-15499].

734 **References**

735 Albers, R., & Johnson, B. (2016). Community service learning: Successfully engaging
736 emirati business students. *International Journal of Learning and Teaching*, 2(2),
737 161–166. <https://doi.org/10.18178/ijlt.2.2.161-166>

738 American Psychological Association. (1997). Proceedings of the American
739 Psychological Association, Incorporated, for the year 1996: Minutes of the Annual
740 Meeting of the Council of Representatives: August 8 and 11, 1996, Toronto,
741 Ontario, Canada, and February 21–23, 1997, Washington, DC. *American*
742 *Psychologist*, 52(8), 813–868. <https://doi.org/10.1037/0003-066X.52.8.813>

743 Barlow, A., & Brown, S. (2020). Correlations between modes of student cognitive
744 engagement and instructional practices in undergraduate STEM courses.
745 *International Journal of STEM Education*, 7(1), 18. [https://doi.org/10.1186/s40594-](https://doi.org/10.1186/s40594-020-00214-7)
746 [020-00214-7](https://doi.org/10.1186/s40594-020-00214-7)

747 Bédard, D., Lison, C., Dalle, D., & Boutin, N. (2010). Predictors of student's engagement
748 and persistence in an innovative PBL curriculum: Applications for engineering

749 education. *International Journal of Engineering Education*, 26(3), 511–522.
750 <https://doi.org/10.7771/1541-5015.1355>

751 Bédard, D., Lison, C., Dalle, D., Côté, D., & Boutin, N. (2012). Problem-based and
752 Project-based Learning in Engineering and Medicine: Determinants of Students'
753 Engagement and Persistence. *Interdisciplinary Journal of Problem-Based Learning*,
754 6(2), 8–22. <https://doi.org/10.7771/1541-5015.1355>

755 Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The*
756 *Clearing House: A Journal of Educational Strategies, Issues and Ideas*, 83 (2) ,
757 39–43 . [http s : / / doi . org / 10.1080/00098650903505415](http://doi.org/10.1080/00098650903505415)

758 Ben-Eliyahu, A., Moore, D., Dorph, R., & Schunn, C. D. (2018). Investigating the
759 multidimensionality of engagement: Affective, be- havioral, and cognitive
760 engagement across science activities and contexts. *Contemporary Educational*
761 *Psychology*, 53, 87–105. [https:// doi.org/10.1016/j.cedpsych.2018.01.002](https://doi.org/10.1016/j.cedpsych.2018.01.002)

762 Blumenfeld, P. C., & Meece, J. L. (1988). Task factors, teacher behav- ior, and students'
763 involvement and use of learning strategies in science. *The Elementary School*
764 *Journal*, 88(3), 235–250. <https://doi.org/10.1086/461536>

765 Blumenfeld, P. C., Puro, P., & Mergendoller, J. R. (1992). Translating motivation into
766 thoughtfulness. In I. H. H. Marshall (Ed.), *Redefining student learning: Roots of*
767 *educational change* (pp. 207–239). Ablex. Botella Nicolás, A. M., & Ramos Ramos,
768 P. (2020). La relación con los demás y la motivación en un Aprendizaje Basado en
769 Proyectos. *Estudios Pedagógicos (Valdivia)*, 46(1), 145–160.
770 <https://doi.org/10.4067/S0718-07052020000100145>

- 771 Brundiers, K., & Wiek, A. (2013). Do we teach what we preach? An international
772 comparison of problem- and project-based learning courses in sustainability.
773 *Sustainability*, 5(4), 1725–1746. <https://doi.org/10.3390/su5041725>
- 774 Byrne, B. M. (2013). *Structural equation modeling with LISREL, PRELIS, and SIMPLIS*.
775 Psychology Press. <https://doi.org/10.4324/9780203774762> Cents-Boonstra, M.,
776 Lichtwarck-Aschoff, A., Lara, M. M., & Denessen,
777 E. (2021). Patterns of motivating teaching behaviour and student engagement: A
778 microanalytic approach. *European Journal of Psychology of Education*, 37(1), 227–
779 255. <https://doi.org/10.1007/s10212-021-00543-3>
- 780 Chen, J., Kolmos, A., & Du, X. (2021). Forms of implementation and challenges of PBL
781 in engineering education: A review of literature. *European Journal of Engineering*
782 *Education*, 46(1), 90–115. <https://doi.org/10.1080/03043797.2020.1718615>
- 783 Cheng, S.-Y. (2013). An empirical investigation of the effectiveness of project-based
784 course learning within hospitality programs: The mediating role of cognitive
785 engagement. *Journal of Hospitality, Leisure, Sport & Tourism Education*, 13, 213–
786 225. <https://doi.org/10.1016/j.jhlste.2013.10.002>
- 787 Cheung, G. W., & Rensvold, R. B. (2002). Evaluating goodness-of-fit indexes for testing
788 measurement invariance. *Structural Equation Modeling: A Multidisciplinary*
789 *Journal*, 9(2), 233–255. https://doi.org/10.1207/S15328007SEM0902_5
- 790 Christenson, S. L., Reschly, A. L., & Wylie, C. (2012). *Handbook of research on student*
791 *engagement*. Springer. <https://doi.org/10.1007/978-1-4614-2018-7>

- 792 Connell, J. P., & Wellborn, J. G. (1991). Competence, autonomy, and relatedness: A
793 motivational analysis of self-system processes. In M. Gunnar & L. A. Sroufe (Ed.),
794 The Minnesota symposia on child psychology Vol. 23. Self process and development
795 (pp. 43–77). Lawrence Erlbaum Associates, Inc.
- 796 Corno, L., & Mandinach, E. B. (1983). The role of cognitive engage- ment in classroom
797 learning and motivation. *Educational Psychologist*, 18(2), 88–108.
798 <https://doi.org/10.1080/00461528309529266>
- 799 Csikszentmihalyi, M., Rathunde, K., & Whalen, S. (1993). Talented teen- agers: The
800 roots of success and failure. Cambridge University Press.
- 801 Csikszentmihalyi, M., & Schneider, B. (2000). *Becoming adult: How teenagers prepare*
802 *for the world of work*. Basic Books.
- 803 Curran, P. J., West, S. G., & Finch, J. F. (1996). The robustness of test statistics to
804 nonnormality and specification error in confirmatory factor analysis. *Psychological*
805 *Methods*, 1(1), 16–29. <https://doi.org/10.1037/1082-989X.1.1.16>
- 806 Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human*
807 *behavior*. Plenum.
- 808 Elliot, A. J., & Dweck, C. S. (2005). *Handbook of competence and motivation*.
809 Guilford Press.
- 810 Frank, M., Lavy, I., & Elata, D. (2003). Implementing the project-based learning
811 approach in an academic engineering course. *International Journal of Technology*
812 *and Design Education*, 13(3), 273–288. <https://doi.org/10.1023/A:1026192113732>

813 Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement potential of
814 the concept. *Review of Educational Research*, 74(1), 59–109.
815 <https://doi.org/10.3102/00346543074001059>

816 Fredricks, J. A., Wang, M., Te, Schall Linn, J., Hofhens, T. L., Sung, H., Parr, A., &
817 Allerton, J. (2016). Using qualitative methods to develop a survey measure of math
818 and science engagement. *Learning and Instruction*, 43, 5–15.
819 <https://doi.org/10.1016/j.learnin-struct.2016.01.009>

820 Hafen, C. A., Allen, J. P., Mikami, A. Y., Gregory, A., Hamre, B., & Pianta, R. C. (2012).
821 The pivotal role of adolescent autonomy in secondary school classrooms. *Journal*
822 *of Youth and Adolescence*, 41(3), 245–255. [https://doi.org/10.1007/s10964-011-9739-](https://doi.org/10.1007/s10964-011-9739-2)
823 [2](https://doi.org/10.1007/s10964-011-9739-2)

824 Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R.L. (2006). *Multivariate*
825 *data analysis* (6th ed.). Pearson Prentice Hall. Hardre, P. L., & Reeve, J. (2003). A
826 motivational model of rural students' intentions to persist in, versus drop out of,
827 high school. *Journal of Educational Psychology*, 95(2), 347–356.
828 <https://doi.org/10.1037/0022-0663.95.2.347>

829 Harter, S. (1978). Effectance motivation reconsidered. *Human Development*, 21(1),
830 34–64. <https://doi.org/10.1159/000271574>

831 Haughery, J., & Raman, D. (2016). A systematic review of mechatronic-based projects
832 in introductory engineering and technology courses [Paper presentation]. 2015
833 ASEE Annual Conference and Exposition Proceedings.

- 834 Hektner, J. M., & Asakawa, K. (2001). Learning to like challenges. In B. S.
835 Csikszentmihalyi (Ed.), *Becoming adult* (pp. 95–112). Basic Books.
- 836 Hospel, V., Galand, B., & Janosz, M. (2016). Multidimensionality of behavioural
837 engagement: Empirical support and implications. *International Journal of*
838 *Educational Research*, 77, 37–49. <https://doi.org/10.1016/j.ijer.2016.02.007>
- 839 Jaeger, M., & Adair, D. (2018, June). Impact of PBL on engineering students' motivation
840 in the GCC region: Case study [Paper presentation]. 2018 Advances in Science
841 and Engineering Technology International Conferences (ASET) (pp. 1–7). IEEE.
842 <https://doi.org/10.1109/icaset.2018.8376918>
- 843 Jang, H., Kim, E. J., & Reeve, J. (2012). Longitudinal test of self-determination theory's
844 motivation mediation model in a naturally occurring classroom context. *Journal*
845 *of Educational Psychology*, 104(4), 1175–1188. <https://doi.org/10.1037/a0028089>
- 846 Jang, H., Kim, E. J., & Reeve, J. (2016). Why students become more engaged or more
847 disengaged during the semester: A self-determination theory dual-process model.
848 *Learning and Instruction*, 43, 27–38.
849 <https://doi.org/10.1016/j.learninstruc.2016.01.002>
- 850 Jimerson, S. R., Campos, E., & Greif, J. L. (2003). Toward an understanding of
851 definitions and measures of school engagement and related terms. *The California*
852 *School Psychologist*, 8(1), 7–27. <https://doi.org/10.1007/BF03340893>
- 853 Kelly, S. (2008). Race, social class, and student engagement in middle school English
854 classrooms. *Social Science Research*, 37(2), 434–448.
855 <https://doi.org/10.1016/j.ssresearch.2007.08.003>

856 Klem, A. M., & Connell, J. P. (2004). Relationships matter: Linking teacher support to
857 student engagement and achievement. *The Journal of School Health* , 74 (7), 262–
858 273. <https://doi.org/10.1111/j.1746-1561.2004.tb08283.x>

859 Koch, F. D., Dirsch-Weigand, A., Awolin, M., Pinkelman, R. J., & Hampe, M. J. (2016).
860 Motivating first-year university students by interdisciplinary study projects.
861 *European Journal of Engineering Education*, 42(1), 17–31.
862 <https://doi.org/10.1080/03043797.2016.1193126>

863 Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learn- ing: A review of
864 the literature. *Improving Schools*, 19(3), 267–277.
865 <https://doi.org/10.1177/1365480216659733>

866 Larson, R. (2011). Adolescents' conscious processes of developing reg- ulation:
867 Learning to appraise challenges. In R. M. Lerner, J. V.

868 Lerner, E. P. Bowers, S. Lewin-Bizan, & S. Gestsdottir (Eds.), *Thriving in childhood and*
869 *adolescence: The role of self regulation processes: New directions for child and*
870 *adolescent development* (pp. 87–97). Jossey-Bass.

871 Lee, M. J. W., Nikolic, S., Vial, P. J., Ritz, C., Li, W., & Goldfinch, T. (2016). Enhancing
872 project-based learning through student and in- dustry engagement in a video-
873 augmented 3-D virtual trade fair. *IEEE Transactions on Education*, 59(4), 290–298.
874 <https://doi.org/10.1109/TE.2016.2546230>

875 Li, S., Zheng, J., & Lajoie, S. (2020). Efficient clinical reasoning: Knowing when to start
876 and when to stop. *Education in the Health Professions*, 3(1), 1.
877 https://doi.org/10.4103/EHP.EHP_1_20

878 Liu, W. C., Wang, C. J., Tan, O. S., Koh, C., & Ee, J. (2009). A self-determination
879 approach to understanding students' motivation in project work. *Learning and*
880 *Individual Differences*, 19(1), 139–145. <https://doi.org/10.1016/j.lindif.2008.07.002>

881 Makkonen, T., Tirri, K., & Lavonen, J. (2021). Engagement in learning physics through
882 project-based learning: A case study of gifted Finnish upper-secondary-level
883 students. *Journal of Advanced Academics*, 32(4), 501–532.
884 <https://doi.org/10.1177/1932202X211018644>

885 Midgley, C., Maehr, M. L., Hruda, L. Z., Anderman, E., Anderman, L., Freeman, K. E.,
886 Gheen, M., Kaplan, A., Kumar, R., Middleton,
887 M. J. Nelson, J., Roeser, R., & Urdan, T. (2000). *Manual for the patterns of adaptive*
888 *learning sciences (PALS)*. University of Michigan Press.

889 Mikami, A. Y., Boucher, M. A., & Humphreys, K. (2005). Prevention of peer rejection
890 through a classroom-level intervention in middle school. *The Journal of Primary*
891 *Prevention*, 26(1), 5–23. <https://doi.org/10.1007/s10935-004-0988-7>

892 Morais, P., Ferreira, M. J., & Veloso, B. (2021). Improving student engagement with
893 project-based learning: A case study in Software Engineering. *IEEE Revista*
894 *Iberoamericana de Tecnologías Del Aprendizaje*, 16(1), 21–28.
895 <https://doi.org/10.1109/RITA.2021.3052677>

896 Morrison, J., Frost, J., Gotch, C., McDuffie, A. R., Austin, B., & French, B. (2020).
897 Teachers' role in students' learning at a project-based STEM high school:
898 Implications for teacher education. *International Journal of Science and*

899 Mathematics Education, 19(6), 1103–1123. <https://doi.org/10.1007/s10763-020->
900 10108-3

901 Nelson, N. J. (2016). Student engagement and project-based learning in the social
902 studies classroom. [http://digitalcommons.hamline.edu/cgi/](http://digitalcommons.hamline.edu/cgi/viewcontent.cgi?article=5244&context=hse_all)
903 [viewcontent.cgi?article=5244&context=hse_all](http://digitalcommons.hamline.edu/cgi/viewcontent.cgi?article=5244&context=hse_all)

904 Newmann, F. M. (1992). Student engagement and achievement in American secondary
905 schools. Teachers College Press.

906 Oh, J.-E., Chan, Y. K., & Kim, K. V. (2020). Social media and E-portfolios: impacting
907 design students' motivation through project-based learning. IAFOR Journal of
908 Education, 8(3), 41–58. <https://doi.org/10.22492/ije.8.3.03>

909 Orji, C. T., & Ogbuanya, T. C. (2020). Mediating roles of ability beliefs and intrinsic
910 motivation in PBL and engagement in practical skills relations among
911 electrical/electronic education undergraduate. Innovations in Education and
912 Teaching International, 59(3), 326–336.
913 <https://doi.org/10.1080/14703297.2020.1813188>

914 Pöysä, S., Vasalampi, K., Muotka, J., Lerkkanen, M.-K., Poikkeus, A.- M., & Nurmi, J.-E.
915 (2018). Variation in situation-specific engagement among lower secondary school
916 students. Learning and Instruction, 53, 64–73.
917 <https://doi.org/10.1016/j.learninstruc.2017.07.007>

918 Prigmore, M., Taylor, R., & De Luca, D. (2016). A case study of au- tonomy and
919 motivation in a student-led game development project. Computer Science
920 Education, 26(2–3), 129–147. <https://doi.org/10.1080/08993408.2016.1210854>

921 Prince, M., & Felder, R. (2007). The many faces of inductive teaching and learning.
922 Journal of College Science Teaching, 36(5), 14–20.
923 <https://doi.org/2200/20080506115505992T>

924 Putnick, D. L., & Bornstein, M. H. (2016). Measurement invariance conventions and
925 reporting: The state of the art and future directions for psychological research.
926 Developmental Review : DR, 41, 71–90. <https://doi.org/10.1016/j.dr.2016.06.004s>

927 Reeve, J., & Jang, H. (2006). What teachers say and do to support students' autonomy
928 during a learning activity. Journal of Educational Psychology, 98(1), 209–218.
929 <https://doi.org/10.1037/0022-0663.98.1.209>

930 Reeve, J., Jang, H., Carrell, D., Jeon, S., & Barch, J. (2004). Enhancing students'
931 engagement by increasing teachers' autonomy support. Motivation and Emotion,
932 28(2), 147–169. <https://doi.org/10.1023/B:MOEM.0000032312.95499.6f>

933 Ruzek, E. A., Hafen, C. A., Allen, J. P., Gregory, A., Mikami, A. Y., & Pianta, R. C.
934 (2016). How teacher emotional support motivates students: The mediating roles of
935 perceived peer relatedness, auton- omy support, and competence. Learning and
936 Instruction, 42, 95–103. <https://doi.org/10.1016/j.learninstruc.2016.01.004>

937 Schaddelee, M., & McConnell, C. (2018). Analysing student perceptions to enhance
938 engagement: An interdisciplinary, project-based learning programme. Journal of
939 International Education in Business, 11(2), 161–177. [https://doi.org/10.1108/JIEB-09-](https://doi.org/10.1108/JIEB-09-2017-0034)
940 [2017-0034](https://doi.org/10.1108/JIEB-09-2017-0034)

941 Shernoff, D. J. (2013). Optimal learning environments to promote student engagement.
942 Springer.

943 Shernoff, D. J., Kelly, S., Tonks, S. M., Anderson, B., Cavanagh, R. F., Sinha, S., & Abdi,
944 B. (2016). Student engagement as a function of environmental complexity in high
945 school classrooms. *Learning and Instruction*, 43, 52–60.
946 <https://doi.org/10.1016/j.learninstruc.2015.12.003> Sirin, S. R., & Rogers-Sirin, L.
947 (2004). Exploring school engagement of middle-class African American
948 adolescents. *Youth & Society*, 35(3), 323–340.
949 <https://doi.org/10.1177/0044118X03255006>

950 Skinner, E., Furrer, C., Marchand, G., & Kindermann, T. (2008). Engagement and
951 disaffection in the classroom: Part of a larger motivational dynamic? *Journal of*
952 *Educational Psychology*, 100(4), 765–781. <https://doi.org/10.1037/a0012840>

953 Stolk, J. (2009). Nurturing creative processes and attitudes in introduc- tory materials
954 science [Paper presentation]. 2009 Annual Conference & Exposition Proceedings.
955 <https://doi.org/10.18260/1-2-5158>

956 Sukerti, G. N., Yuliantini, N. N., & Susana, K. Y. (2018). Students' voices and choices in
957 project-based learning: Driving engagement through essay writing and
958 infographic design. *Advances in Social Science, Education and Humanities*
959 *Research*, 226, 607–618. <https://doi.org/10.2991/icss-18.2018.122>

960 Torrijo, F. J., Garzón-Roca, J., Cobos, G., & Eguibar, M. Á. (2021). Combining project
961 based learning and cooperative learning strategies in a geotechnical engineering
962 course. *Education Sciences*, 11(9), 467. <https://doi.org/10.3390/educsci11090467>

963 Umar, M., & Ko, I. (2022). E-learning: Direct effect of student learn- ing effectiveness
964 and engagement through project-based learning, team cohesion, and flipped

965 learning during the COVID-19 pan- demic. *Sustainability*, 14(3), 1724.
966 <https://doi.org/10.3390/su14031724>

967 Wang, H. Y., Huang, I., & Hwang, G. J. (2016). Effects of a question prompt-based
968 concept mapping approach on students' learning achievements, attitudes and 5C
969 competences in project-based com- puter course activities. *Educational Technology
970 and Society*, 19(3), 351–364.

971 Wang, J., Tigelaar, D. E. H., Luo, J., & Admiraal, W. (2022). Teacher beliefs, classroom
972 process quality, and student engagement in the smart classroom learning
973 environment: A multilevel analysis. *Computers & Education*, 183, 104501.
974 <https://doi.org/10.1016/j.compedu.2022.104501>

975 Wu, S.-J., Han, J., Sun, F.-R., Wan, R.-G., & Zhao, Y.-Q. (2021). An integrated model for
976 exploring college students' engagement and competence development in flipped
977 learning using partial least squares path modeling. *Interactive Learning
978 Environments*, 1–20. <https://doi.org/10.1080/10494820.2021.1881799>

979 Zedan, R. (2010). New dimensions in the classroom climate. *Learning Environments
980 Research*, 13(1), 75–88. <https://doi.org/10.1007/s10984-009-9068-5>

981 Zhang, J., Scardamalia, M., Reeve, R., & Messina, R. (2009). Designs for collective
982 cognitive responsibility in knowledge-building com- munities. *Journal of the
983 Learning Sciences*, 18(1), 7–44. <https://doi.org/10.1080/10508400802581676>

984 Zhang, J., Xie, H., & Li, H. (2018). Project based learning with im- plementation
985 planning for student engagement in BIM classes. *International Journal of
986 Engineering Education*, 35(1), 310–322.

987 Zirkel, S., Garcia, J. A., & Murphy, M. C. (2015). Experience-sampling research methods
988 and their potential for education research. *Educational Researcher*, 44(1), 7–16.
989 <https://doi.org/10.3102/0013189X14566879>