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Understanding the engagement of elementary school students in one-to-one iPad programs using an adaptation of self-system model of motivational development

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ABSTRACT

The number of one-to-one mobile programs in elementary schools as a resource that substitutes the textbook has become popular in worldwide. However, studies that seek to understand how the daily use of these mobile devices is associated with teaching/learning practices and student's engagement in the classroom are lacking. The authors utilized and adapted a self-system model of motivational development in order to better understand the mechanisms behind the promotion of academic engagement through the use of iPads. For this, an analysis using structural equations was conducted on the data collected from a network of 20 elementary schools and 1977 K-5/6 students in Spain, who used iPads daily in their Language, Mathematics, Science and Second Language subjects. The data showed that the pedagogic method acted as a mediator between iPad use in the classroom and academic engagement, as it satisfied the psychological needs of the students. The study contributes with a comprehensive approach that results in an increase of knowledge on the reasons behind the success of failure of these types of programs on learner engagement.

1. Introduction

The latest developments in mobile technology have created a new gamut of digital tools for learning equipped with a tactile screen, such as the iPad from Apple, with a wide array of applications. These developments entail their recognition by many schools as viable options for outfitting their students with a learning resource that satisfies today's demands. In fact, schools have been increasingly including them as a resource, substituting textbooks (Ihaka, 2013; Falloon, 2013). These programs, with one-to-one mobile devices, are becoming more popular around the world (Hershkovitz & Karni, 2018).

A characteristic that is common to these programs is that each student (and teacher) has a mobile device (normally a laptop or a tablet). Nevertheless, there are different implementations, such as (a) programs where the students can take the device home, (b) bring their own device to school, and (c) the school buys a set number of devices, which are stored and distributed in the classrooms according to the teacher's wishes (Penuel, 2006).

Given the growing popularity of these types of programs, there has been an increase in research on their effects, the activities in the classroom and the learning experiences (Fleischer, 2012). In this sense, there are numerous studies that have found that the student's participation in these programs improved their motivation and commitment with the tasks (Lowther, Inan, Strahl, & Ross, 2012; Lin, Wong, & Shao, 2012; Donovan, Green & Hartley, 2010; Downes & Bishop, 2012), as well as their learning abilities (e.g., Spektor-Levy & Granot-Gilat, 2012). However, there are also studies that have shown that the inclusion of mobile devices (i.e. iPad) was not sufficiently significant in the increase in commitment or learning of the students (e.g., Carr, 2012) as compared to conventional schools (or experiences).

Research in this area has allowed for an increased understanding that part of this heterogeneity is due, among other reasons, to the learning ecology found in a classroom with one-to-one devices (Spires, Oliver, & Corn, 2011). With the student's commitment being closely related with

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the results, in the review by Fleischer (2012), the lack of studies that delved into learning situations that stimulate different levels of motivations and commitment was underlined. "The results of the review generally show that individual and small group collaborative learning settings increases motivation in one-to-one projects" (p. 119). Also, there is a need to delve into the teaching strategies that are most adequate for the one-to-one projects, as well as the type of activities that are most stimulating for students (Weston & Bain, 2010).

Given the growing trend of one-to-one programs in educational policies for the integration of ICT in primary education in Spain and the heterogeneity of their results (Area-Moreira et al., 2014), the objective of this study was to understand one of the mechanisms that make it possible for one-to-one iPad programs to promote students' engagement with academic tasks in four main subjects in the primary education curriculum in Spain.

To respond to this objective, the authors used the self-system model from Connell (Skinner, Furrer, Marchand, & Kindermann, 2008) as a reference. According to this perspective, individuals have fundamental psychological needs for relatedness, autonomy and competence. The degree in which students perceive that these needs are being satisfied in the classroom determines the engagement these students will have with academic tasks and at school (Jang, Kim, & Reeve, 2016; Jang, Reeve, Ryan & Kim, 2009).

Based on these assumptions, the authors postulate that the daily use of mobile devices (iPads) in one-to-one programs is associated with students' academic engagement as long as the activities (with iPads) are associated with a learning ecology that satisfies the psychological needs for autonomy, relatedness and competence.

To verify that this is true, the authors tested these hypotheses in the main subjects of the Primary Education curriculum in Spain - language, mathematics, science and foreign language -, and in K-5 and K-6 grades because it is the educational cycle mainly addressed in previous educational policies for the inclusion of ICTs in classrooms.

Likewise, considering that the type of subject and the educational level taught by the teacher can affect the pedagogic integration of the mobile devices in one-to-one programs, the authors monitored both factors to verify these differences in the model.

2. Theoretical framework

Next, on the basis of the self-system model, the authors outline the arguments for the research model used.

2.1. Engagement and satisfaction of student needs

The student's 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, & Reeve, 2012; Ladd & Dinella, 2009; Lippmann, 2013; Rocca, 2010). It is a multidimensional construct comprised by four interconnected aspects that are mutually re-enforced. Namely: behavior, emotional, cognitive and social involvement (Christenson, Reschly, & Wylie, 2012; Fredricks, Blumenfeld, & Paris, 2004; Fredricks et al., 2016; Wang, Fredricks, Ye, Hofkens, & Linn, 2016).

Likewise, being the engagement a malleable state, the self-determination theory argues that the lack of engagement of the students depends on their psychological needs. This theory highlights the importance of the students satisfying their needs for autonomy, competency and relatedness (Ryan & Deci, 2000). As these three needs are satisfied, the functionality of the class improves, and a psychological well-being appears that motivates the students to become engaged with learning (Jang et al., 2009; Vansteenkiste, Simons, Lens, Sheldon, & Deci, 2004; Jang et al., 2012).

2.2. Self-system model of motivational development (SSM)

The self-system model of motivational development (SSM) (Connell, 1990) is one of the more-explicit conceptualizations of engagement, broadened by Skinner et al. (2008). According to this perspective, the student's needs are satisfied and the engagement increases, as far as the contextual factors allow it. In other words, the engagement is greater in the classrooms where the teachers support the student's autonomy; where the teachers have high expectations and provide clear and consistent feedback; and where the tasks are variable, challenging, interesting and significant (Cheon & Reeve, 2015; Hospel & Galand, 2016; Jang et al., 2010, 2016; Skinner et al., 2008).

This process (Skinner et al., 2008) is represented in Fig. 1.

2.2.1. Learning context in one-to-one programs

The review conducted by Fleischer (2012) highlights the need to delve into the learning strategies that are adequate for the one-to-one projects (pg. 120). Spires et al. (2011) suggested a type of learning ecology for the one-to-one projects based on four specific conditions: (a) constant and immediate access to the information; (b) the capacity for learning to be personalized, intense and relevant; (c) the capacity for the students to self-manage, being creative and curious; and (d) that the teacher act as a facilitator, consultant and mentor.

In this sense, authentic learning is a pedagogic approach that is compatible with all the characteristics of the context defined in the SSM and in the learning ecology posit by Spires et al. (2011), focused in providing autonomy to the students, orientation, significant tasks and a close relationship between students and professors (Herrington, Reeves, & Oliver, 2014; Lombardi, 2007). The conceptual foundations of authentic learning are linked to the theory of "Situated Cognition" by Brown and Duguid (2000), based on the study of the interactions of highly successful learning. The key for the achievement of these interactions is to provide situations that mirror the manner in which knowledge will be useful in real life real (Brown, Collins, & Duguid, 1988). This focus seeks that the learning experiences be based on the complexity of the real world whose solutions are complex, utilizing activities based on problems, case studies and participation in communities of practice (Herrington et al., 2014).

Authentic (situated) learning is one of the underlying pedagogic approaches that are most used in studies on the use of mobile devices in the teaching of language (Sung, Chang, & Yang, 2015), mathematics and science (Bano, Zowghi, Kearney, Schuck, & Aubusson, 2018).

There are many empirical studies that have shown that the use of mobile devices can improve students' engagement (Ditzler, Hong, & Strudler, 2016), in that they promote significant and authentic learning. For example, the study by Cheng, Yang, Chang, and Kuo (2016) showed an improvement of engagement when providing improved practical learning, even though it was necessary to develop activities that were significant. In this sense, teachers who develop experiences that encourage students to participate in activities allowing them to collaborate amongst themselves instead of interacting in an isolated manner with the content, will provide students with the possibility of experiencing significant learning (e.g., Heflin, Shewmaker, & Nguyen, 2017; Lumpkin, Achen, & Dodd, 2015).

3. Research questions and hypotheses

The research found heterogeneous results with respect to the effects of the participation of students in one-to-one mobile programs on engagement (Irish, 2017). The review by Fleischer (2012) allowed concluding that part of this heterogeneity was due to the learning context developed by teachers in the one-to-one program classrooms (Spires et al., 2011). However, surprisingly little is known about the learning strategies that increase the learning in these types of programs (Fleischer, 2012; Irish, 2017).

Nevertheless, in the absence of a model that will enable the

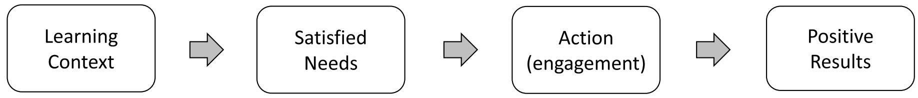

Fig. 1. Self-system model of motivational development (Skinner et al., 2008).

understanding of the mechanisms that make it possible for one-to-one mobile programs to promote the academic engagement of students, the authors utilized an adaptation of the self-system model of motivational development (SSM) to empirically prove the sequence represented in Fig. 2. I.e., the authors postulate that the daily use of mobile devices (iPad) in one-to-one programs will promote the academic engagement of students to the extent that the activities (with an iPad) promote authentic learning (e.g., Ditzler et al., 2016; Heflin et al., 2017), satisfying the psychological needs for autonomy, relatedness and competency.

This sequence is represented in Fig. 2.

One of the expectations of one-to-one programs is their ability to change from a teacher-centered approach to a student-centered one (Fleischer, 2012; Penuel, 2006).

Through the review by Fleischer (2012), it could be verified that generally, in one-to-one programs, the collaborative small-group or individual learning environments increased student commitment.

However, the individual-social dichotomies should be interpreted as related aspects that must be equilibrated towards more-balanced conceptions (Garrison, 2000; Watson & Coulter, 2008). Likewise, these types of environments require the teacher to act as a facilitator of learning (Lee, Spires, Wiebe, Hollebrands, & Young, 2015; Spires et al., 2011). Therefore, the authors posited the following hypotheses (Fig. 3):

(H1). Considering that the activities seek equilibrium (balance), the individual setting and small group setting (through the iPad), are supported by the teacher (H1a and H1b, respectively), and are associated amongst themselves (H1c).

(H2). The individual and small group setting (through the use of an iPad), are associated with authentic learning (H2a and H2b, respectively).

H3. A high level of authentic learning is associated with the satisfied needs.

H4. A high level of satisfaction of the student's needs is associated with student engagement (behavioral engagement, cognitive engagement. affective engagement, and social engagement).

The richness derived from dealing with these four components of engagement, creates the challenge of defining each one and to see their combination (interaction) in conceptually nuanced ways. For example, it is likely that emotional engagement will lead to an increase in behavioral engagement (e.g., Taboada Barber, Buehl, Kidd, Sturtevant, Richey Nuland, & Beck, 2014), or that social engagement is associated with cognitive engagement (e.g., Wanstreet & Stein, 2011; Tirado--Morueta, Maraver-López, Hernando-Gomez, & Harris, 2016), which mediate the later successes (Fredricks et al., 2004). In order to shed some light to these questions, the following hypotheses were postulated:

(H5). Affective engagement towards the class subject is associated with behavioral engagement (H5a), and likewise, social engagement is associated with cognitive engagement (H5b).

Moderation of the type of subject. The subject studied is one of the aspects that has an impact on the effective implementation of one-to-one technology (Larkin & Finger, 2011). Some studies have shown that the subject matter being taught can have an impact on the integration of the technology in one-to-one programs (Howard, Chan, & Caputi, 2015). Likewise, this could be associated to the beliefs of teachers on the specific characteristics of their class subject (Zuber & Anderson, 2013).

The authors used the subject as a moderating variable of context learning (H1a, H1b, H1c, H2a, H2b) and controlled the four main subjects in primary education in Spain (language, mathematics, science, and foreign languages).

4. Method

4.1. Participants and data collection

The data collection process was conducted in a network composed of 20 private centers, in which the use of the iPad® was compulsory and daily in the K-5/6 grades and 40 classrooms. The teachers of the study respondents had a minimum experience of eight years in one-to-one iPad programs. Students could take the iPads to their homes to carry out their academic activities.

The research was composed by studies focused on four subjects: (a) 504 students from Language, (b) 507 from Mathematics, (c) 466 students from the Sciences, and (d) 500 students from second language-English. The total sample was comprised by 1977 students, 49.92% were male and 51.08% were female, and 49.62% were K-5 and 51.38% were K-6.

The data collection process was the following: The institution's management was contacted to inform them about the research study. After receiving the formal approval of the centers, authorization was requested to the parents and guardians of the respondents. The technology coordinator was clearly informed about the objectives of the study, the anticipated benefits and the related process of investigation. The measurement instruments were provided to the technology coordinator so that he or she could evaluate them with respect to their adequacy for the context of the study. The coordinator's observations were taken into account, and some items were adjusted. However, members of the research team explained all the questionnaire questions to the respondents. Participation was voluntary, and the anonymity of those polled was maintained.

4.2. Measurements

Measurement of the learning setting through the iPad. (a) A total of 14 items which represented *individual and social activities* considered in the framework by Falloon (2013), to analyze the use of the iPad, and which differentiated structured/open actions of cognitive effort (trial-error, examples, problem solving, gamification …), the teacher's responses (scaffolding, orientation, corrections …) and the work techniques (collaborative or individual). (b) The items were grouped in three

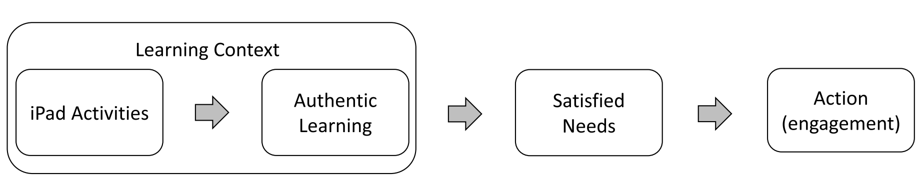

Fig. 2. Research model.

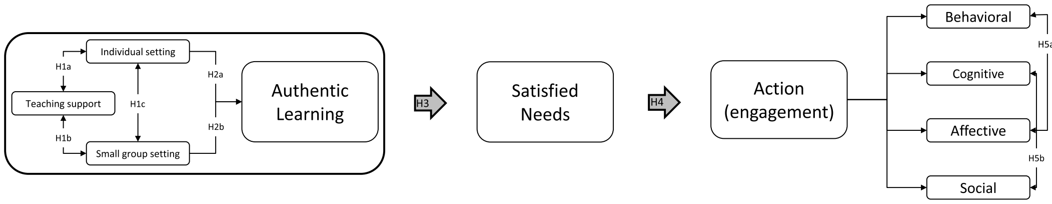

Fig. 3. Hypotheses tested.

dimensions: individual settings (IS), small group setting (SGS), and teaching support (TS). (c) The item groups were contextualized through interviews with a group of 8 teachers of the subjects considered in the study (Table 1). (d) A five-point response scale was used, which ranged from 1 (never) to 5 (daily). (e) A confirmatory factorial analysis was performed to identify the factorial structure of the constructs (learning activities), using the maximum likelihood method with Varimax rotation.

To verify the unidimensionality of each construct, a principal component analysis was performed for each construct and in each study, using the criteria by Kaiser (1960). The results of the analysis showed that only the value of the first component for all the constructs was >1.

To measure reliability Cronbach's Alpha and composite reliability (CR) were calculated. The results had values that were higher than the recommended value (≥0.70), except for individual setting (IS) (Alpha = .56).

To measure convergent validity, the following were analyzed: (a) the average variance extracted (AVE), with a minimum recommended value of 0.5; and (b) the factorial load of each indicator. The data on the AVE showed that all the constructs obtained values that were close to or higher than the recommended value, except IS (0.44).

To measure discriminant validity, the $\sqrt{AVE}$ of each construct was calculated, verifying that its value was greater than its Pearson's correlation with the rest of the constructs.

Appendix A show the results of the analysis of validity of each construct.

Measurement of authentic learning (AL). To measure this construct, the scale by Herrington and Parker (2013) was utilized, and a four-point response scale was used, which ranged from 1 (never) to 4 (always).

Measurement of satisfied needs. To measure this construct, the following scales were utilized:

- Autonomy (AU) (Ruzek, Hafen, Allen, Gregory, Mikami, & Pianta, 2016). This scale was comprised by 3 items and four response options that ranged from 1 (never) to 4 (always).
- Relatedness (RE) (Mikami, Boucher, & Humphreys, 2005). This scale contained 2 items and four response options that ranged from 1 (none) to 4 (always).
- Competence (CO) (Midgley et al., 2000). This scale had 3 items and four answer options that ranged from 1 (it is not true) to 4 (completely true).

Measurement of engagement (EN). To measure this multi-dimensional construct, adaptations of the scales used by Fredricks et al. (2004; 2016), and Wang et al. (2016) were used. The dimensions measured were behavioral engagement (BE) (5 items), affective engagement (AE) (4 items), cognitive engagement (CE) (4 items) and social engagement (SE) (4 items). These dimensions were measured through four-point scales that ranged from 1 (never) to 4 (always).

Likewise, in order to verify the validity of the constructs (AL, AU, RE, CO, BE, AE, CE and SE), the properties of unidimensionality, reliability, convergent validity and discriminant validity, were analyzed.

The one-dimensional analysis showed that only the value of the first component, for all the constructs was >1, except for construct AL, where a bi-dimensional structure was observed (AL_{Task} and $AL_{Teaching}$). The AL_{Task} dimension refers to aspects related to the authenticity of the subject and the task, and the $AL_{Teaching}$ dimension referred to the teaching-learning dynamics.

With respect to reliability, in all the constructs, the CR obtained acceptable values except the alpha value of the RE construct was low (α = 0.40). As for the convergent validity, AVE results were acceptable, with values of 0.43 in BE up to .74 in AL_{Task}.

In order to test the discriminating validity, $\sqrt{AVE}$ was calculated for each construct, and it was verified that their value was higher than their Pearson's correlation with the rest of the constructs.

Appendix B and C show the results of the analysis of the four properties.

4.3. Data analysis

In order to test the hypothesis posited in Fig. 3, Structural Equation Modeling (SEM) was used with the Amos 18.0 software. According to this modeling method, each theory consists of a set of correlations, and if the theory is valid, then the correlation patterns (suppositions) can be reproduced in empirical data (Byrne, 2013).

Through SEM, it is possible to statistically test the theoretical model through a simultaneous analysis of all the variables and their relationships, in order to verify to what degree the proposed model is consistent with the data. In the case that the goodness-of-fit is suitable, the model supports the plausibility of the relationships presented. However, if it's unsuitable, the plausibility of the model is rejected. With the aim of measuring the goodness-of-fit of the model, the indices that are usually used for the three categories of model adjustment (Hair, Black, Babin, Anderson, & Tatham, 2006) (absolute, parsimonious and incremental) were utilized.

The following adjustment criteria were established following the recommendations of Hair et al. (2006) for 12 ≤ n observed variables ≥ 30 and N > 250. For the absolute measurements of adjustment the χ 2 (p > .05) and the root mean square error of approximation (RMSEA) was used (0 < RMSEA<0.07). For the incremental measurement of fit, the comparative fit index (CFI) was used (0.92 < CFI<1). Lastly, for the measurement of parsimonious fit, the normed χ^2 (χ^2/df) was used ($1<\chi^2/df<2$–5).

In order to test the moderation of the subject and control the grade (K-5 & K-6), the invariance (equivalence) of the model for the four subjects (Language, Mathematics, Science & Second Language) and the two grades, a multi-group analysis was executed using the AMOS v.18 software. Measurement invariance refers to the degree to which the parameters of the measurement model are similar among the groups and was evaluated at its three levels: weak model (invariance of factorial loads of latent variables), partial model (invariance of all factorial loads -except H2a and H2b- and covariances –except H1a, H1b, and H1c-) and strict model (invariance of all factorial loads and covariances). In the case that the strict invariance is met, we could not attest that there was moderation of the variable (subject or grade) in the context of learning (H1a, H1b, H1c, H2a, & H2b). Likewise, in the case that the weak and partial invariance is met, and not the strict one, it could be attested that the variable (subject or grade) acts as the moderator of the context of learning.

In order to analyze the invariance, the tests recommended by Byrne (2013) were used, starting with the determination of a good fit of the configural multigroup model, which will serve as the base model with

Table 1
Contextualization of item groups.

	Example (real)	Applications used
Small group setting. The students work as a team, do projects, games in teams and class presentations.	"Short group work sessions are proposed daily for a final project. For example, the review of a text to improve it with the collaboration of peers; for the objective of reading with expressiveness, a fragment of a play, and after viewing it, they act it out". (Teacher L).	Safari Kahoot Keynote iMovie
	"Each unit is presented as group work. For example, making a mural that explains the decimals or the geometric shapes." (Teacher M)	Keynote iMovie
	"For example, if the subject of animals is going to be explained (mammals, amphibians …), they search on the Internet for their information, and prepare presentations as a team." (Teacher S).	Safari Keynote
	"In the project Beatrix Potter, each group acts out a story … they act out situations in life when the standards of courtesy are explained, greetings, short dialogues using the vocabulary explained …. " (Teacher SL).	Keynote Showbie Kindle
Teaching support. The teacher proposes ideas, guides (individually/group), resolves doubts (individually/group), corrects and resolves doubts (individually/group).	"Guidelines are presented daily on how to work, doubts are resolved, and the work is corrected afterwards. For example, in a session working with oral expression … I proposed that they search for information on the Internet, to study the different characteristics of the expression according to the context (academic, leisure, etc.) and to use the audio-visual support to present their findings (Teacher L)	Safari Keynote iDoceo Blinklearning
	"The questions from the previous class are answered daily (i.e. decimals), through individual as well as group exercises." (Teacher M).	Blinklearning Safari iDoceo
	For example, I explain the muscles in the body, I ask them to access the material compiled in Showbie, they see it, and they ask me …" (Teacher S).	Showbie Keynote
	It is real and helps in the group and the individual as well, or the universe and the solar system; According to the day's subject: vocabulary about the family, food, grammatical questions.	ITunes Showbie
Individual settings. The students work individually, read and play.	"Individual readings and exercises are conducted daily. For example, readings proposed in the book, selected, that are close to their interests, to promote written expression: reading. Or creating short texts, poems …" (Teacher L).	Polygon Education Safari
	"We do individual exercises daily, for example, individual calculation strategies; the equivalence between the elements of the Decimal Number System or fractions …" (Teacher M).	Safari iMovie King of Math
	"To review previous subjects, they watch the videos there, read the text and resolve the activities proposed." (Teacher S)	Keynote iMovie
	"For example, listening and written exercises on interrogative sentences …" (Teacher SL).	iTunes

which the rest of the more restrictive models will be compared. For comparing restrictive models, previous research studies have used the Chi-square difference test ($\Delta\chi 2$). 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.

5. Results

5.1. Basic model

Firstly, a statistical analysis was conducted in order to examine the assumption of normality of the variables used in the structural equation model. In this case, the Komogorov-Smirnov test was not used, as it is too sensitive when using large sample sizes. Therefore, an analysis of skewness and kurtosis (see Table 2) was conducted. These analyses according to Curran, West, and Finch (1996), establish the limits, in absolute values, until the behavior can be considered close to normal, for the values between 2 for asymmetry and 7 for kurtosis. The results showed that the values from both statistical tests complied with this rule, so that the condition of normality was accepted.

Secondly, in order to improve the adjustment indices, a re-specification of the original model was made, suppressing the factorial loads that did not exceed the minimum value required of 0.50, so that the RE variable was eliminated from the model.

Table 3 and Fig. 4 show the regression and correlations indices of all the associations and variances established in basic model. It can be observed that all the parameters were significant (except CE ↔ SE) and the variances of the model variables had values between 0.16 y 0.85.

After testing the causal structure of each model, the indices of adjustment obtained were acceptable: $\chi 2/df = 7.06$; RMSEA = 0.05 (90% confidence interval [CI] = 0.04, 0.06); NFI = 0.949; IFI = 0.956 and CFI = 0.956. The high value of $\chi 2/df$ established could be due to its

Table 2
Descriptive results of the constructs.

	Mean	SD	Skewness (SE)	Kurtosis (SE)
BE	3.01	.57	-.62 (0.05)	.19 (0.11)
AE	3.20	.66	-.85 (0.05)	.27 (0.11)
CE	3.28	.54	-.90 (0.05)	.91 (0.11)
SE	3.41	.49	−1.05 (0.05)	1.72 (0.11)
AL_{Task}	3.11	.71	-.66 (0.05)	.04 (0.11)
$AL_{Teaching}$	3.28	.55	-.92 (0.05)	.89 (0.11)
AU	3.01	.67	-.54 (0.05)	-.01 (0.11)
RE	3.29	.52	-.60 (0.05)	.33 (0.11)
CO	3.25	.56	-.90 (0.05)	1.19 (0.11)
SGS	3.62	.94	-.73 (0.05)	.20 (0.11)
IS	4.18	.75	−1.09 (0.05)	1.23 (0.11)
TS	4.35	.77	−1.74 (0.05)	3.29 (0.11)

Table 3
Hypotheses and fit of the basic model.

Hypotheses	Basic Model	
	r	Beta
H1a. TS ↔ SGS	.42***	
H1b. TS ↔ IS	.41***	
H1c. SGS ↔ IS	.29***	
H2a. SGS → AL		.26***
H2b. IS → AL		.23***
H3. AL → SN		.88***
H4. SN → EN		.92***
H5a. BE ↔ AE	.48***	
H5b. CE ↔ SE	n.s.	
SGS → EN (indirect effect)		.21
IS → EN (indirect effect)		.19
AL → EN (indirect effect)		.80
R^2 Authentic Learning (AL)	.16	
R^2 Satisfied needs (SN)	.77	
R^2 Engagement (EN)	.85	
R^2 Behavioral Engagement (BE)	.22	
R^2 Cognitive Engagement (CE)	.54	
R^2 Affective Engagement (AE)	.25	
R^2 Social Engagement (SE)	.41	
χ^2/df		7.06
NFI		.949
IFI		.956
CFI		.956
RMSEA		.05 (.049–.062)

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

sensitivity to sample size.

Once the good fit of the model was demonstrated, the relationships were analyzed to verify the validity of the hypotheses and thus determine the predictive capacity of the model. The analysis showed the variance of the latent variables engagement, satisfied needs and authentic learning, with values greater than 0.85, 0.77 and 0.16, respectively.

Regarding the latent variable engagement, its factorial load was composed by the variables observed: social engagement (0.84), cognitive engagement (0.74), affective engagement (0.50) and behavioral engagement (0.47). The model also explained 41% of the variance of the social engagement variable, 54% of the cognitive engagement variable, 25% of the affective engagement variable, and 22% of the behavioral engagement variable.

Regarding the satisfied needs variable, its factorial load was composed by the observed variables autonomy (0.63) and competence (0.54), and the model explained 39% of the autonomy variable and 30% of the competence variable.

Regarding the authentic learning variable, its factorial load was composed of the observed task (0.57) and teaching (0.79) variables, and the model explained 33% of the task variable and 72% of the teaching variable.

All hypotheses were accepted –across course and grade-except H5b. Both interrelated SGS and IS (H1c) and supported by teacher (H1a and H1b), showed a significant association with authentic learning (AL) (H2a & H2b, respectively). Likewise, AL showed a strong association with the satisfaction of needs (SN) of autonomy (AU) and competence (CO) (H3). Lastly, SN showed a strong association with academic engagement (EN) (H4).

5.2. Multi-group analysis

Table 4 and Fig. 5 show the regression and correlations indices of all the associations established in configural model, as well as the variances explained from each subject (Language, Mathematics, Science, and Second Language).

After testing the causal structure of each model, the indices of adjustment obtained were acceptable (Table 5):

- Configural model across subjects: $\chi 2/df = 3.00$; RMSEA = 0.03 (90% confidence interval [CI] = 0.02, 0.05); and CFI = 0.94.

The analysis showed the variance of the engagement, satisfied needs and authentic learning across subjects, with values greater than 0.69, 0.68 and 0.14, respectively. Likewise, the values across grades were up to .79, .74 and 0.12, respectively.

All hypotheses were accepted –across subject and grade-except H5b.

Finally, the invariance test across subjects and grades was performed.

- Across subjects: The values of p ($\Delta\ \chi 2$) in the restrictive models, weak and strong, were not significant. Moreover, there was no significant deterioration in the CFI value with respect to the configural model ($\Delta CFI_{weak} = 0.001$; $\Delta CFI_{partial} = 0.002$). However, in the strict model the CFI value did have a significant deterioration ($\Delta CFI_{strict} = 0.015$). Therefore, it can be confirmed that the subject moderated the context of learning.

Since the strict invariance test showed that the parameters (H1a, H1b, H1c, H2a & H2b) were not equivalent between subjects, in order to compare the differences between covariance parameters, the recommendations of Byrne and Van de Vijver (2010) were followed, and the critical ratio (CR) difference method offered by AMOS was used. If the critical ratios exceed 1.96, the parameter is significantly different between the two groups at a level of $p < .05$.

Table 6 show critical ratios between covariance parameters across subject.

Regarding the moderation of the subject:

H1a. (TS ↔ SGS), significant differences there was between Language and Mathematics (CR = 5.94; $p < .001$), Sciences (CR = 2.74; $p < .001$) and Second Language (CR = 2.86; $p < .001$). Likewise, between Mathematics and Science (CR = −3.41; $p < .001$) and Second Language (CR = −3.66; $p < .001$). Therefore, in Mathematics the small group settings had a teacher support stronger than in the other subjects.

H1b. (TS ↔ IS), there were significant differences between Mathematics and Language (CR = 2.87; $p < .001$) and Second Language (CR = −2.87; $p < .001$). Therefore, in Mathematics the individual setting had a teacher support stronger than in the other subjects.

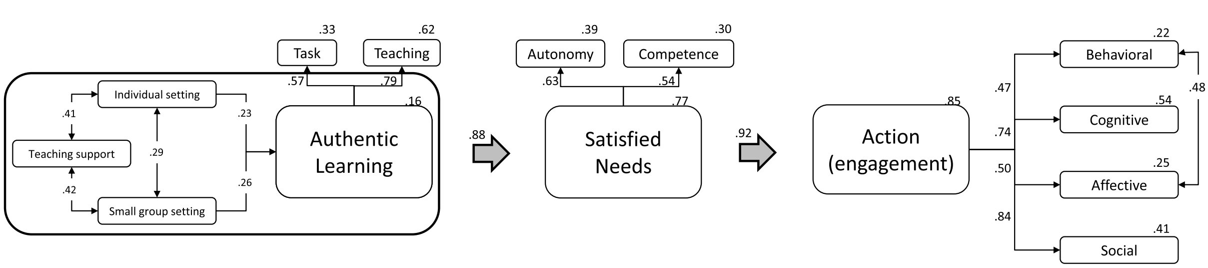

Fig. 4. Structure of the basic model.

Table 4
Hypotheses in muti-group analysis.

Hypothesis	Subject							
	Language		Mathematics		Science		Second Language	
	r	Beta	r	Beta	r	Beta	r	Beta
H1a. TS ↔ SGS	.32***		.48***		.39***		.42***	
H1b. TS ↔ IS	.43***		.49***		.36***		.41***	
H1c. SGS ↔ IS	.23***		.24***		.41***		.48***	
H2a. SGS → AL		.28***		.25***		.33***		.26***
H2b. IS → AL		.22***		.23***		.20***		.20***
H3. AL → SN		.89***		.81***		.99***		.82***
H4. SN → EN		.92***		.92***		.83***		1.02 ***
H5a. BE ↔ AE	.43***		.48***		.51***		.50***	
H5b. CE ↔ SE	n.s.		n.s.		n.s.		n.s.	
SGS → EN (indirect effect)		.22		.18		.28		.22
IS → EN (indirect effect)		.18		.17		.16		.17
AL → EN (indirect effect)		.81		.75		.82		.85
R^2 Authentic Learning (AL)	.15		.14		.20		.16	
R^2 Satisfied needs (SN)	.78		.68		.98		.68	
R^2 Engagement (EN)	.85		.84		.69		1.05	
R^2 Behavioral Engagement (BE)	.27		.23		.21		.19	
R^2 Cognitive Engagement (CE)	.59		.48		.62		.46	
R^2 Affective Engagement (AE)	.26		.24		.27		.24	
R^2 Social Engagement (SE)	.45		.42		.39		.38	

$^*p < .05$; $^{**}p < .01$; $^{***}p < .001$.

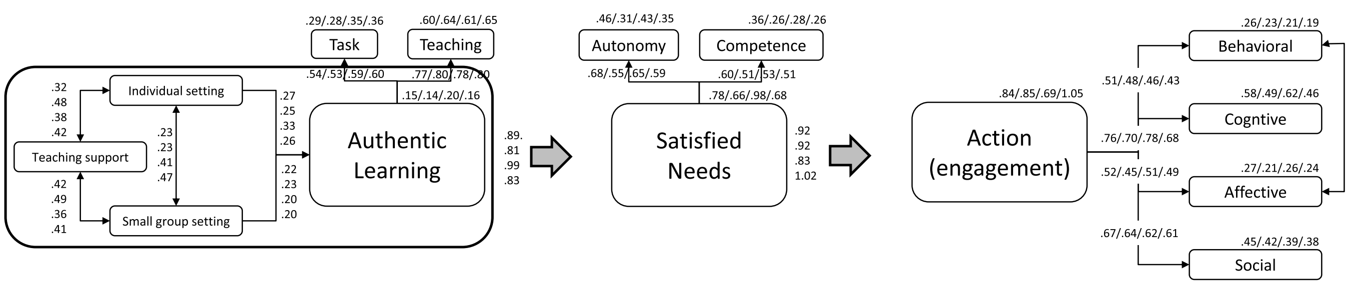

Fig. 5. Structure of the model across subjects.
Note: Values from top to bottom (and from left to right) indicate Language, Mathematics, Science and Second Language coefficients.

Table 5
Measurement invariance tests across courses/subjects and grades.

	$\chi^2(df)$	$\Delta\ \chi^2$	p ($\Delta\ \chi^2$)	χ^2/df	RMSEA (90% CI)	CFI	Δ CFI
Subjects							
Configural model	467.96 (156)			3.00	.032	.944	
Weak model	474.77 (168)	6.81	.870	2.82	.030	.945	.001
Partial model	490.50 (177)	22.54	.368	2.77	.030	.943	.002
Strict model	586.54 (192)	118.58	.000	3.05	.032	.929	.015
Grades							
Configural model	383.62 (78)			4.91	.045	.944	
Weak model	409.61 (83)	25.98	.000	4.93	.045	.940	.004
Partial model	411.35 (86)	28.12	.001	4.72	.043	.940	.004
Strict model	443.19 (91)	59.56	.000	4.91	.045	.935	.009

H1c. (SGS ↔ IS), there were significant differences between Language and Science (CR = 4.03; $p < .001$) and Second Language (CR = 4.49; $p < .001$). Therefore, in Language the association between individual setting and small group setting was less than in Science and Second Language subjects.

Table 6
Critical ratios between parameters cross subjects.

	Language	Mathematics	Science
H1c. Small group setting ↔ Individual setting			
Language			
Mathematics	1,86		
Science	4.03***	1.60	
Second Language	4.49***	1.54	0.02
H1a. Teaching support ↔ Small group setting			
Language			
Mathematics	5.94***		
Science	2.74***	−3.41***	
Second Language	2.86***	−3.66***	−0.11
H1b. Teaching support ↔ Individual setting			
Language	0		
Mathematics	2.87***	0	
Science	0.85	−1.74	
Second Language	−0.02	−2.87***	−0.86
H2a. Small group setting → Authentic learning			
Language			
Mathematics	−1.82*		
Science	0.41	2.35**	
Second Language	−0.67	1.10	−1.11
H2b. Individual setting → Authentic learning			
Language			
Mathematics	0.14		
Science	0.42	−0.55	
Second Language	−0.04	−0.17	0.34

H2a. (SGS → AL), there were significant differences between Mathematics and Language (CR = −1.81; $p < .05$) and Science (CR = 2.35; $p < .001$). This means that the connection between learning in small groups and authentic learning was significantly inferior in mathematics as compared to language and sciences.

H2b. (IS → AL), no significant differences were found.

6. Discussion and implications

There is literature that demonstrates that the efficacy of one-to-one mobile programs in the engagement of learners is determined (partially) by a student-centered learning context (Fleischer, 2012). Nevertheless, there is a lack of studies that help with an in-depth understanding of the instructional strategies that are adequate for these programs and their connection with students' engagement. The present study sought to understand the mechanisms that make daily iPad use in the classroom stimulate students' engagement, in terms of behavior, affectivity, cognitive effort and positive social relationships with peers.

For this purpose, the authors tried a sequence based on the self-system model of motivational development. The analysis of the model's invariance showed the validity of the sequence across subjects (Language, Mathematics, Science and Second Language) and grades (K-5 and K-6). Nevertheless, the data showed that the type of subject moderated the learning context. This means that depending on the subject, the connections between the individual and small group activities, the importance of teacher's support, as well as the connection between learning in small groups and authentic learning, will vary.

The first component of the sequence was the set of activities (set of individual actions), identified from the framework by Falloon (2013) for the pedagogical analysis of the use of mobile applications, and the settings (efficient) identified in one-to-one programs (Fleischer, 2012). The set of activities were contextualized in two types of settings (individual and small group setting) supported by the teacher.

Firstly, the equilibrium between the individual and small group settings was corroborated in these subjects and grades (Park, 2011; Garrison, 2000; Watson & Coulter, 2008). However, in Language the association between individual and small group settings was weaker than in Science and Second Language subjects. Secondly, the teaching support in Mathematics was stronger than in the other subjects.

The second component of the sequence was the relationship between the learning settings (with the iPad) and the pedagogic approach of authentic learning. In this sense, it was verified that the individual and social activities were related amongst themselves (balanced) and associated to the variable of authentic learning.

The third component of the sequence referred to the association between the variables authentic learning and the satisfaction of needs. In this sense, the data of this study showed that this pedagogic approach (indirectly) affected the engagement, through the satisfaction of needs related to autonomy and competence (self-efficacy). In other words, the authentic learning construct (Herrington & Parker, 2013) satisfied the demands from the contextual factors (autonomy, structure and group cohesion) described in the self-system model of motivational development (adapted by Skinner et al., 2008).

The fourth component, the relationship between the satisfaction of needs (autonomy and competence) and engagement (in its different facets), was corroborated just as predicted by the self-system model by Connell (Connell, 1990). Lastly, the data of the study showed an association between the behavioral and affective engagement, corroborating the findings by Taboada Barber et al. (2014).

Across subjects, the activities conducted with the iPad that promote an authentic pedagogy were both conducted in teams, based on the completion of projects, which utilized games and concluded in class presentations, as individual and structured activities. These activities were conducted with the support of the teacher, acting as a coach (providing ideas and orientation), scaffold (when resolving their doubts), and shaping progress when correcting the student's doubts.

Therefore, the activities (with an iPad) where the students interacted with the applications, thereby collaborating with other peers, seemed to have a greater probability for promoting authentic learning as compared to those in which the students interacted individually with their applications (Heflin et al., 2017; Lumpkin et al., 2015), satisfying their needs for autonomy, relationships and self-efficacy, resulting in engagement with the subject.

In general, this study has furthered the understanding of the mechanisms that explain students' engagement during the learning process in one-to-one iPad programs, using an adaptation of the self-system model of motivational development. On the one hand, this study has shown that mobile applications integrated into meaningful learning activities indirectly connect with students' engagement. On the other hand, the data has shown that the nature of the subjects moderates learning dynamics with the use of the iPad.

The findings of this study emphasize the relevance of the learning context and the significance of didactic activities as stimuli for the commitment of students when using mobile devices. Considering the growing popularity of one-to-one mobile programs worldwide (Hershkovitz & Karni, 2018), educational policies should strengthen teacher training based on meaningful practices and adapted to the nature of the subjects. It seems evident that the technological advances implemented in mobile applications (e.g., augmented reality, internet of things, social networks …) broaden the opportunities for meaningful and stimulating learning experiences in the classroom. However, it is necessary to overcome the "fascination" caused by technology and move towards an intelligent use based on didactic criteria and considering the needs of students.

7. Conclusions

In order to conduct this study, data was collected from 20 elementary schools and 1977 students in K5 and K-6 grades, who had substituted the textbook for the iPad for their daily activities at school for 8 years.

In order to understand how to promote the students' engagement, the authors tested a sequence by adapting the model of self-system of motivational development in Language, Mathematics, Science and Second Language subjects and in K-5 and K-6. The data showed, firstly, the usefulness of this model for understanding the mechanisms that explained the academic engagement of the students when using the iPad. Secondly, it was shown that authentic learning satisfied the students' psychological needs for autonomy and competence (self-efficacy).

Thirdly, the data showed that the pedagogic method of authentic learning acted as a mediator between the use of the iPad in the classroom and academic engagement, as it satisfied the needs of the students.

Fourth, the data showed that there was an indirect association on engagement of the learning setting in the interaction with the teaching support, when promoting significant learning and satisfying the students' needs.

Lastly, the multi-group analysis showed that the type of subject moderated the context of learning. Thus, the importance of the teacher's support in small group and individual activities, as well as the equilibrium between both types of activities, will vary depending on the type of subject.

Previous reviews have emphasized that contradicting results related to the learning benefits in one-to-one programs were greatly dependent on the inexperience of the teacher and the context of learning. However, there are no concluding data on the pedagogic aspects of these programs that connect with engagement and academic performance. This study has tried a comprehensive model of analysis that will allow for the advancement in more subtle aspects of the method and the mobile technology in one-to-one programs.

8. Limitations and future studies

The study had a few limitations that could guide other researchers in future studies. Firstly, the study utilized self-reports that were similar to others used in studies to measure the authentic learning constructs, satisfaction of needs, and different facets of engagement, so that the use of other qualitative records could be complementary (e.g., Falloon, 2013). Secondly, although the authors utilized a pilot study to identify learning setting, it would be appropriate to conduct a previous qualitative recording of the individual actions (by the teacher and students) through classroom observations, among other instruments.

With respect to future studies, this model of analysis could be used for studies that compare different versions of the teaching-learning method and mobile applications in different education subjects and grades. It is not enough to know the level of pedagogic change (i.e. SAMR model) implied by the use of technologies in one-to-one programs, but the understanding of the reasons behind the improvement of the results is also important.

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Declaration of competing interest

The authors declare that they have no conflict of interest.

Appendix A

		Load	AVE	Alpha	CR
Small group setting (SGS)	When we use the iPad in the classroom we:				
	„ play as a team	.78	.67	.83	.89
	„ make presentations in the classroom	.80			
	„ do team projects	.86			
	„ work as a team	.83			
Individual setting (IS)	I use the iPad individually for:				
	„ demostrations and examples	.63	.44	.56	.75
	„ problem's solutions	.67			
	„ practical exercises	.73			
	„ Individual work	.61			
Teaching support (TS)	The teacher:				
	„ guides me	.79	.55	.83	.87
	„ corrects me while I am learning something	.67			
	„ solves the group's questions	.77			
	„ solves my questions	.73			
	„ guides the group	.81			
	„ proposes ideas to the group	.67			

Appendix B

		Load	AVE	Alpha	CR
Behavioral engagement (BE)	I am centered	.66	.43	.68	.79
	I answer the questions	.66			
	I put effort on learning	.65			
	I ask in class	.66			
	I perform the activities that my teacher gives me on time	.66			
Affective engagemento (AE)	I like this subject	.78	.57	.75	.85
	I enjoy learning new things in this subject.	.76			
	I want to understand what we learn in this subject	.73			
	I feel good in class	.77			
Cognitive engagement (CE)	I check the class homework to ensure it is correct	.73	.50	.66	.79
	I think about different ways of solving a task	.73			
	I try to connect what I learn with what I already know	.71			
	I try to learn from my mistakes when I do it wrong	.63			
Social engagement (SE)	I consider the ideas from my classmates	.70	.48	.64	.79
	I try to understand the ideas from my classmates	.74			
	I try to work with others who I know can help me.	.64			
	I try to help others who have difficulties.	.70			
Authentic learning – Task (AL_{Task})	The topics done in class are connected with real life	.86	.74	.65	.85
	The tasks are similar to the ones I would have in real life	.86			
Authentic learning - Teaching ($AL_{Teaching}$)	I see examples that help me understand better.	.68	.50	.75	.83
	The topics are presented from multiple points of view	.62			
	The teacher makes me think about the topics studied by:	.71			
	.. encouraging me to express myself	.77			
	.. explaining and guiding us when necessary	.74			
Autonomy (AU)	We make decisions about how to develop the class	.79	.53	.55	.77
	We decide how to perform the group tasks	.71			

(continued on next page)

(*continued*)

		Load	AVE	Alpha	CR
Competence (CO)	We feel we can help to lead the class	.67	.60	.66	.82
	I can do all the tasks that are proposed in class	.75			
	I am sure I will master all the contents of this year	.77			
	Even if the tasks are difficult I am sure I will make them correctly	.80			

Appendix C

Correlations between variables and the $\sqrt{AVE}$ of each variable

	BE	AE	CE	SE	AL_1	AL_2	AU	CO	SGS	IS	TS
BE	*.66*										
AE	.60**	***.76***									
CE	.33**	.37**	***.70***								
SE	.30**	.28**	.48**	***.69***							
AL_1	.26**	.29**	.31**	.29**	***.86***						
AL_2	.28**	.32**	.45**	.40**	.44**	***.70***					
AU	.29**	.34**	.40**	.35**	.35**	.43**	***.72***				
CO	.27**	.18**	.42**	.32**	.27**	.36**	.32**	***.77***			
SGS	.13**	.12**	.18**	.16**	.14**	.28**	.20**	.12**	***.81***		
IS	.13**	.15**	.19 **	.13**	.13**	.25**	.18**	.13**	.29**	**.66**	
TS	.13**	.12**	.17**	.19**	.19**	.38**	.21**	.13**	.41**	.41 **	***.75***

Note: the square root of the variance is shown in italics.
*$p < .05$. **$p < .01$

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