QUESTIONNAIRE

Latent factors on the design and adoption of gamified apps in primary education

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1.- Introducción

This questionnaire has been developed within the framework of the "Proof of Concept" Project entitled: "GAUBI-ORTO. Evaluation of a digital model and application for sustainable, ubiquitous and gamified learning of Spanish spelling in Primary Education" (PDC2022-133185-I00). State Program to Promote Scientific-Technical Research and its Transfer, of the State Plan for Scientific and Technical Research and Innovation. Ministry of Science and Innovation (Spain)

2.- Validity and reliability of the questionnaire

The Cronbach Alpha coefficient was above 0.8 and the Kaiser-Meyer index exceeded 0.78. The null hypothesis was rejected by the Bartlett sphericity test, thus enabling factor analysis. Factor analysis yielded seven factors with the varimax rotation method, thus confirming the validity of the questionnaire. The maximum likelihood estimation method was used to calculate the structural model's parameters. Although the data did not conform to the multivariate normal distribution, this method facilitated the convergence of estimates (Lévy et al., 2006). The model was assessed on criteria from Bollen (1989) and Rindskopf and Rose (1988), who proposed that the measurement model and structural model be evaluated separately. The measurement model's validity and reliability were analyzed, the latter in terms of the reliability of the items and of each construct. For validity, both convergent and discriminant validity were analyzed, with the results shown in Tables 1 and 2.

Table 1
Standardized estimations

Factors		λ	Cronbach's α	CR (Composite Reability)	AVE
Curriculum Connection			0.923	0.901	0.755
CC1	Curriculum Con.	0.843			
CC2	Curriculum Con.	0.834			
CC3	Curriculum Con.	0.811			
CC4	Curriculum Con.	0.789			
CC5	Curriculum Con.	0.823			
Feedback and Operational Experience			0.911	0.902	0.814
FO1	Feedback and op. experience	0.787			
FO2	Feedback and op. experience	0.866			
FO3	Feedback and op. experience	0.815			
FO4	Feedback and op. experience	0.889			
FO5	Feedback and op. experience	0.811			
FO6	Feedback and op. experience	0.865			
Assessment and Learning analytics			0.944	0.851	0.712
AL1	Assessment and L. Analytics	0.821			
AL2	Assessment and L. Analytics	0.832			
AL3	Assessment and L. Analytics	0.822			
AL4	Assessment and L. Analytics	0.818			
Sustainable (Protection Personal data)			0.923	0.944	0.881
SP1	Sustainable (Prot. Personal Data)	0.934			
SP2	Sustainable (Prot. Personal Data)	0.889			

SP3	Sustainable (Prot. Personal Data)	0.921			
SP4	Sustainable (Prot. Personal Data)	0.896			
SP5	Sustainable (Prot. Personal Data)	0.878			
SP6	Sustainable (Prot. Personal Data)	0.923			
SP7	Sustainable (Prot. Personal Data)	0.899			
Equal access			0.833	0.901	0.811
EA1	Equal access	0.887			
EA2	Equal access	0.900			
EA3	Equal access	0.812			
EA4	Equal access	0.834			
EA5	Equal access	0.889			
Flow			0.932	0.901	0.889
FL1	Flow	0.911			
FL2	Flow	0.905			
FL3	Flow	0.923			
FL4	Flow	0.907			
Efficacy			0.931	0.919	0.798
EF1	Efficacy	0.901			
EF2	Efficacy	0.897			
EF3	Efficacy	0.838			
Satisfaction with of an gamified app			0.948	0.938	0.833
SA1	Satisfaction	0.901			
SA2	Satisfaction	0.923			
SA3	Satisfaction	0.971			

Table 1 shows that the reliability of the items is verified. In terms of the reliability of the constructs, all the values for the Cronbach α coefficient and the Composite Reliability (CR) coefficient exceed 0.7, which confirms the reliability of the constructs. Table 1 also shows that the average variance extracted (AVE) is above 0.5, which verifies the constructs' convergent validity. Table 2 presents the results for discriminant validity. For this, the correlation matrix between the constructs was calculated, which confirmed that the correlations were less than the AVE square root.

Table 2
Discriminant validity of measures

	CC	FO	AL	SP	EA	FL	EF	SA
CC	**0.878**							
FO	0.534	**0.814**						
AL	0.551	0.605	**0.805**					
SP	0.612	0.599	0.699	**0.855**				
EA	0.589	0.556	0.678	0.586	**0.871**			
FL	0.711	0.587	0.589	0.702	0.555	**0.787**		
EF	0.721	0.591	0.556	0.713	0.578	0.761	**0.791**	
SA	0.741	0.731	0.665	0.595	0.798	0.613	0.600	**0.901**

Note: the bold numbers of the diagonal are the square root of the AVE. Off-diagonal elements are correlations between constructs.

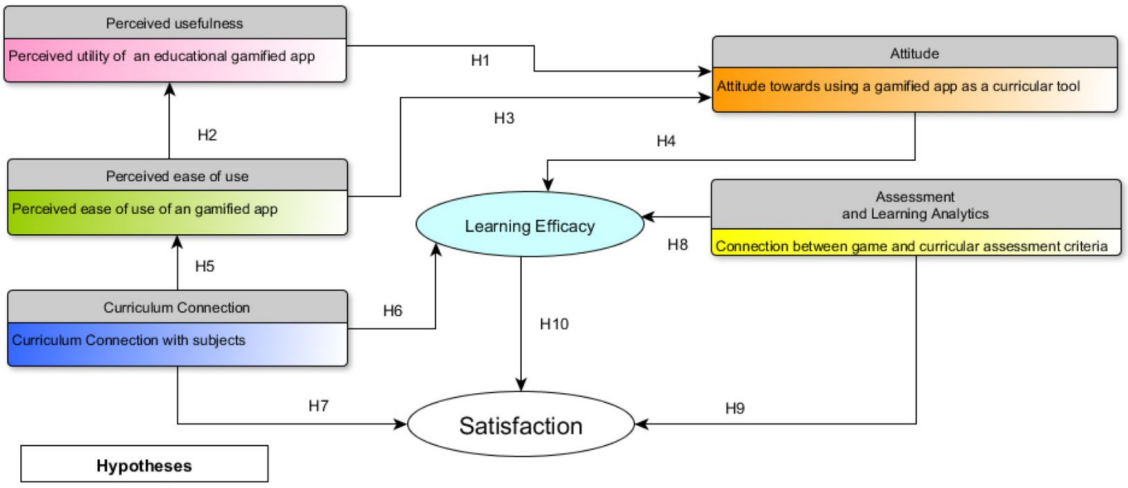
We observed that all correlations between the constructs amount to less than the corresponding AVE values for each construct, thus confirming that the factors measure different concepts. Finally, in assessing the structural model, it was found that the estimated value of the squared coefficient of multiple correlation for each dependent or endogenous construct exceeds 0.5, and that the factor loads between constructs is significant. Table 3 summarizes the structural model and the hypothesis testing results.

Table 3
Parameter estimates

Relation			Estimate	S.E.	C.R.	Standardized estimate	*p*
AS	←	CC	0.567	0.051	15.896	0.565	***
FL	←	FO	0.501	0.053	15.321	0.810	***
AS	←	EF	0.709	0.101	11.781	0.601	***
CC	←	EF	0.401	0.060	12.431	0.541	***
FO	←	EF	0.517	0.041	9.451	0.689	***
SA	←	EA	0.586	0.053	7.621	0.610	***
SA	←	SP	0.612	0.061	9.301	0.502	***
SA	←	EF	0.357	0.100	14.341	0.789	***
SA	←	CC	0.610	0.045	15.001	0.581	***
CC1	←	CC	1			0.843	
CC2	←	CC	0.833	0.102	25.567	0.923	***
CC3	←	CC	0.868	0.031	21.456	0.899	***
CC4	←	CC	1.451	0.071	19.001	0.812	***
CC5	←	CC	1.271	0.063	20.178	0.871	***
FO1	←	FO	1			0.787	
FO2	←	FO	1.201	0.600	16.189	0.901	***
FO3	←	FO	1.205	0.055	15.003	0.837	***
FO4	←	FO	0.913	0.201	16.111	0.834	***
FO5	←	FO	1.401	0.071	15.562	0.886	***
FO6	←	FO	1.108	0.057	9.649	0.891	***
AL1	←	AL	1			0.821	
AL2	←	AL	0.911	0.117	17.300	0.889	***
AL3	←	AL	1.357	0.043	9.643	0.917	***
AL4	←	AL	0.919	0.057	12.134	0.873	***
SP1	←	SP	1			0.934	
SP2	←	SP	1.111	0.055	13.893	0.912	***
SP3	←	SP	1.054	0.132	15.491	0.877	***
SP4	←	SP	1.301	0.063	8.203	0.854	***
SP5	←	SP	1.110	0.071	16.397	0.891	***
SP6	←	SP	0.911	0.051	16.001	0.910	***
SP7	←	SP	1.012	0.055	15.107	0.831	***
EA1	←	EA	1			0.887	
EA2	←	EA	1.006	0.121	11.101	0.876	***
EA3	←	EA	1.131	0.072	10.845	0.818	***
EA4	←	EA	1.145	0.063	14.145	0.895	***
EA5	←	EA	0.998	0.101	8.895	0.913	***
FL1	←	FL	1			0.911	
FL2	←	FL	1.018	0.087	16.117	0.799	***
FL3	←	FL	1.045	0.099	10.009	0.810	***
FL4	←	FL	1.023	0.123	14.176	0.805	***
EF1	←	EF	1			0.901	
EF2	←	EF	1.112	0.079	16.111	0.789	***
EF3	←	EF	1.002	0.011	11.856	0.806	***
SA1	←	SA	1			0.901	
SA2	←	SA	1.001	0.013	32.145	0.819	***
SA3	←	SA	1.021	0.018	35.349	0.845	***

3.- Model and hypotheses

The design of the questionnaire is based on the following research hypotheses:



Hypotheses

Ease-of-use
H1: Perceived usefulness has a positive effect on attitude towards use of an app.
H2: Perceived ease-of-use has a positive effect on perceived usefulness.
H3: Perceived ease-of-use has a positive effect on attitude towards use of the technology.

Attitude
H4: A positive attitude towards use of the technology has a positive effect on learning efficacy.

Curriculum connection
H5: Curricular connection influences perceived ease-of-use.
H6: Curricular connection has a positive effect on learning efficacy.
H7: Curricular connection has a positive effect on satisfaction.

Assessment and Learning analytics
H8: The higher the level of vinculation between assessment criteria and gamified challenges, the greater the influence on learning efficacy.
H9: A higher level of feedback through learning analytics has a positive effect on teachers' satisfaction.

Learning efficacy
H10: The higher the level of learning efficacy, the stronger the positive influence on teachers' satisfaction.

Satisfaction

Figure 1. Hypotheses and dimensions of the questionnaire.

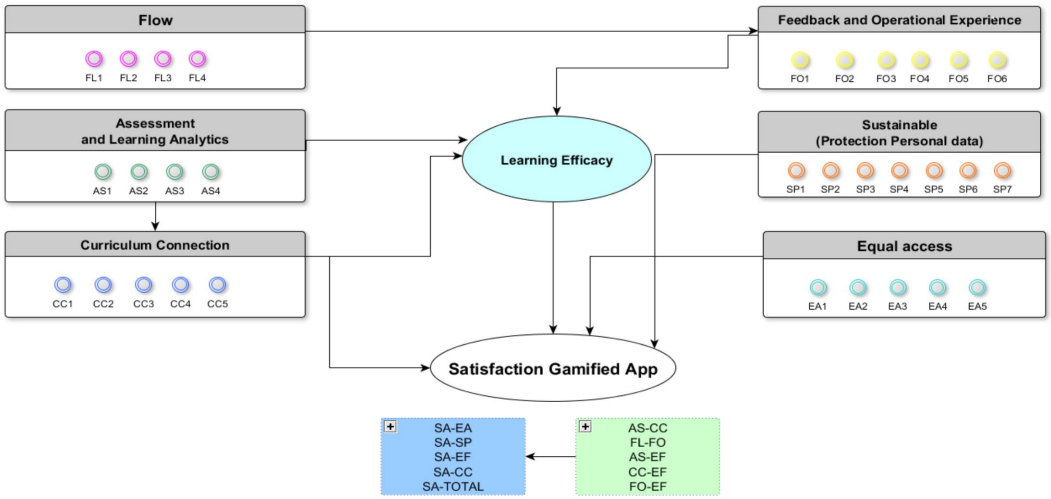


Figure 2. Model of structural equations specified for the derivation of the importance of atributes.

4.- Selected dimensions and attributes for app design measurement

The questionnaire contained eight categories (six latent variables with 37 items). Each item (1-7 scale, 1 meaning "totally disagree" and 7 "totally agree")..

Category	Dimension	Items	Authors
Curriculum Connection	Curriculum Connection	CC1. An educational gamified app should comtemplate the development of specific competencies. CC2. An educational gamified app should comtemplate the development of transversal competencies. CC3. An educational gamified app should comtemplate the development of curricular contents of one or several subjects. CC4. An educational gamified app should comtemplate the development of education in values. CC5. An educational gamified app should integrate learning situations.	Hirsh-Pasek et al. (2015); Lynch & Redpath (2012); Falloon (2013).
Feedback and Operational Experience	Feedback and operational experience on children's game experiece and learning	FO1. An educational gamified app should reinforce cognitive functions (informative, completion, corrective, differentiation, restructuring). FO2. An educational gamified app should reinforce metacognitive functions (informative, specification, corrective, guiding). FO3. An educational gamified app should be motivational (incentive, task facilitation, self-efficacy enhancing, and reattribution). FO4. An educational gamified app should promote self-regulated learning and adaptive scaffolding. FO5. An educational gamified app should be based both on individual and collaborative processes. FO6. The educational gamified app has to provide personalised an adaptive feedback to improve students' performance and to support student reflection.	Shute & Ventura (2013); Deterding et al., (2011). Hamari (2017); Buckley & Doyle (2016); Hamari et al. (2016).
Assessment and Learning analytics	Assessment and Learning Analytics	AS1. The overcoming of challenges in the app should be related to the overcoming of the curriculum evaluation criteria. AS2. The educational gamified app has to provide information about students' performance to parents and teachers. AS3. The educational gamified app has to provide tips to partents to help and control students activity in the app. AS4. The educational gamified app has to provide scales of progress.	Lockyer et al. (2013); Admiraal et al. (2020); Almohammadi et al. (2017); Bernhardt (2017); Charitopoulos et al. (2020); Ifenthaler, D. (2021);
Sustainable (Protection Personal data)	Sustainable and protection of personal data	PD1. App informs on the protection of personal data. PD2. App explains why it asks for permission. PD3. App apllyies an efficient cache policy. PD4. App optimize the use of location services. PD5. App makes decision reversal easyly. PD6. App promotes a safe, flexible and collaborative learning environment. PD7. App guarantees transparency (algorithms and processes).	Baker & Hjarlmarson (2019); Regulation (EU) 2016/679; Feiler et al. (2018); Ooijen & Vrabec (2019).
Equal access	Equal access	EA1. App design ensures that everybody has access to all functionalities. EA2. App optimizes media and images. EA3. App implements Zoom/Magnification (resize text). EA4. App is designed in a consistent layout. EA5. App allows keyboard control for touchscreen devices.	Patch et al. (2015); Directive 2016/2102. Caldwell et al. (2008);
Flow	Design and balance	FD1. App should be designed with clear goals. FD2. App should be designed with the implementation of badges, quests, points and levels. FD3. App should be designed with a balance of skill and challenge. FD4. App should be designed with immersive and intrinsically motivated experiences.	Csikszentmihakvi (2014); Brigham (2015); Hamari & Koivisto (2014); Özhan & Kocadere (2020); Wang et al. (2016).
Efficacy	Learning efficacy	EF1. I believe that the use of an educational gamified app can help me to teach with greater efficacy. EF2. I believe that an educational gamified app can help students to acquire more knowledge. EF3. I believe that an educational gamified app increases students' motivation to learn.	Shoukry et al. (2012); Chau (2014); Chiong & Shuler, (2010); Falloon (2013); Chiong (2012); Hanus & Fox (2015).
Satisfaction	Satisfaction with an gamified app	S1. I am satisfied with the use of an educational gamified app to support the teaching process. S2. I am satisfied with the mobile and ubiquitous learning. S3. An educational gamified app satisfies students' learning needs.	DeLone & McLean (2003); Lee (2010); Lee et al. (2009)