e-ISSN 1135-9250

EDUTEC. Revista Electrónica de Tecnología Educativa

Issue 83 – March 2023

Special issue: Digital technologies in education: focusing on ethics

Analysis of digital sustainability factors in the adoption of learning apps in primary education

Análisis de factores de sostenibilidad digital en la adopción de apps educativas en la Educación Primaria

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Abstract

This article presents a study to measure the importance for teachers of the digital sustainability factors that facilitate or inhibit adoption of learning apps as a support to the teaching-learning process in primary education. A structural equations model methodology was used to conduct the importance-performance analysis (IPA). IPA aims to identify the value alloted by users in terms of the importance and performance of a series of quality criteria to obtain an indirect measure of the elements of digital sustainability that encourage or discourage the adoption of educational apps. The sample was formed by 212 teachers with experience using apps in teaching-learning process. The results indicated four areas of digital sustainability to be improved in order to guarantee good educational and sustainable use of apps inside and outside the classroom: safe and transparent use of data and algorithms, the apps compliance with the functional diversity of all students, the promotion of safe collaborative environments and the need for awareness regarding energy efficiency.

Keywords: app; digital sustainability; data protection; accessibility; energy efficiency; primary education.

Resumen

Este artículo presenta un estudio en el que se mide la importancia para los docentes de los factores de sostenibilidad digital que facilitan o inhiben la adopción de app educativas como apoyo al proceso de enseñanza-aprendizaje en la Educación Primaria. Se ha empleado una metodología basada en un modelo de ecuaciones estructurales para realizar el análisis de importancia-valor (IPA). IPA tiene como objetivo identificar el valor asignado por los usuarios en términos de importancia y desempeño de una serie de criterios de calidad para obtener una medida indirecta de los elementos de sostenibilidad digital que fomentan o desincentivan la adopción app educativas. La muestra estuvo conformada por 212 docentes con experiencia en el uso de apps en el proceso de enseñanza-aprendizaje. Los resultados muestran cuatro áreas de sostenibilidad digital que precisan mejora para garantizar un buen uso educativo y sostenible de las aplicaciones dentro y fuera del aula: uso seguro y transparente de datos y algoritmos, la adecuación de las apps a la diversidad funcional de todos los estudiantes, la promoción de entornos colaborativos seguros y la necesidad de concienciación en materia de eficiencia energética.

Palabras clave: *app, sostenibilidad digital, protección de datos, accesibilidad, eficiencia energética, educación primaria.*

DOI: https://doi.org/10.21556/edutec.2023.83.2715

Received: 26-11-2022
Accepted: 17-02-2023

1. INTRODUCTION

The main aim of this study was to measure the importance for teachers of the factors of digital sustainability that facilitate or inhibit adoption of learning apps as a support to the teaching-learning process in primary education. Digital sustainability in Education is related to the sustainable use of digital devices to teach and learn in a way that guarantees an ethical, responsible, healthy and respectful use, as well as a conscious energy consumption (Vázquez-Cano & Pascual-Moscoso, 2022). In this sense, one of the main competences of teachers is "to take measures to ensure learners' physical, psychological and social wellbeing while using digital technologies. To empower learners to manage risks and use digital technologies safely and responsibly (Punie & Redecker, 2017, p. 23). Based on these premises, teachers must develop critical, creative, digital, and socioemotional skills to feel committed to playing an active role in social changes for a sustainable world (Chaman Cabrera et al., 2023, p. 30). For this purpose, three areas have been identified in the scientific literature: (1) "Safety and ethics in data protection" (Parsons, 2021; Regulation 2016/679; Willis et al., 2016). (2) "Accessibility" (Patch et al., 2015; Directive 2016/2102) and (3) "Green hosting and energy efficiency" (Greenpeace, 2010; Weber et al., 2016).

Digital sustainability is an aspect that particularly concerns teachers and families whenever young people use digital devices online, and is one of the main inhibitors, or precursors, of the use of these devices and apps as a support to the teaching-learning process inside and outside the classroom. Teachers' concerns on digital sustainability regarding the use of learning apps in the classroom were: (1) safety of the data provided by the student when using the learning app; (2) accessibility; (3) energy and ecological efficiency.

1.1. Safety and ethics in data protection

Numerous recent studies have discussed the issue of safety surrounding storage of the information we generate in our daily digital consumption, with the aim of establishing ethical standards for data registration. These studies focused on data use, safety and the ethical principles related to obtaining, use and treatment of personal data. The Association for Educational Communications and Technology (AECT) has defined educational technology as "the study and ethical practice of facilitating learning and improving performance by creating, using and managing appropriate technological processes and resources" (Januszewski & Molenda, 2007, p.1), emphasizing the importance of ethical values in initiatives to promote technology in education. A study by Reyes et al. (2018) analyzed data safety provision in 5,855 free online children's games, concluding that the majority violated the principles established by COPPA (Children´s Online Privacy Protection Act), "one of the few stringent privacy laws in the U.S.", such as tracking and behavioral advertising and noting that "the 19% of children´s apps collect identifiers or other personally identifiable information (PII) via SDKs whose terms of service outright prohibit their use in child-directed apps" (Reyes et al., 2018).

Learning analytics are one of the clearest examples of data gathering to improve users' experience in the school setting, yet compiling data to enhance students' educational experience is also "a potential threat to autonomy and privacy" (Parsons, 2021), so there is understandable concern that the growth in complexity of technological systems should be harnessed by ethical approaches that constantly re-evaluate "the risk that data invade student's privacy" (Willis et al, 2016). Another concern is the false premise that free apps endanger data security more than paid-for apps, hence the notion that "when something is free, you become the product". Both types of apps behave in a similar way in terms of access, data gathering and transmission (Han et al, 2019).

1.2. The principle of accessibility

The main indicators of social inclusion fostered by equal access are the importance of being accepted (Guo et al., 2005, Nkansah & Unwin, 2010, p. 206), forming relationships (Hasan et al, 2017), participation in activities (Guo et al, 2005, Nkansah & Unwin, 2010), access to information on housing (Qureshi, 2016), and employment and support systems (Abascal et al 2016).

The World Wide Web Consortium (W3C) is an international consortium that promotes Internet-based standards and guidelines. These include Web Content Accessibility Guidelines (WCAG) that detail how to make Web content more accessible, in particular for mobile devices. Patch et al. (2015) describe the principles that should guide the design and usability of applications and resources with mobile accessibility, these are: 1) perceivable (small screen size, zoom/magnification and contrast), 2) operable (keyboard control for touchscreen devices, touch target size and spacing, touchscreen gestures, device manipulation gestures and placing buttons where they are easy to access), 3) understable (changing screen orientation (portrait/landscape), consistent layout, provide instructions for custom touchscreen and device manipulation gestures, among others), and (4) robust (set the virtual keyboard to the type of data entry required, provide easy methods for data entry and support the characteristic properties of the platform).

These guidelines were adopted in the European Directive 2016/2022 (EU), requiring member states to enable public service websites and applications to be accessed by mobile devices, ensuring that these portals were "perceiveable, operable, understandable and robust", in order to break down barriers that hinder access by persons with functional diversity. This idea must also be applied to learning apps.

1.3. Green hosting, cloud computing and energy efficiency

Hosting and cloud computing services providers consume vast quantities of energy that feed servers and data centers across the world in order to provide uninterrupted service. The consolidation of services that provide remote access to software, data processing and storage by Internet connection has enabled the development of infrastructure for this purpose by companies such as Google Cloud Services, Amazon AWS, Microsoft Azure or Alibaba Cloud. This has led to the growth of services which, with the energy cost of storing Web content, has substantially increased the environmental costs associated to ICT (Greenpeace, 2010). Research on green computing (Patil & Patil, 2019) has focused on efficient cloud design with ecological characteristics, such as energy management, virtualization, high-performance computing, loading balance, green data centers, reuse or recycling.

The agents responsible for promoting an efficient energy experience in the use of mobile devices are: the user, by adopting good habits such as disconnecting functions not in use during technological sessions, like reducing screen brightness and volume; the manufacturer, who can provide tools to limit app energy consumption via operating system upgrades; and the app developer who, as Liu et al. (2005) pointed out, can ensure adequate functioning and optimization of processes that require greater energy cost, in the form of (1) fluid cloud communication, (2) localization sensors (3) complex calculation processes.

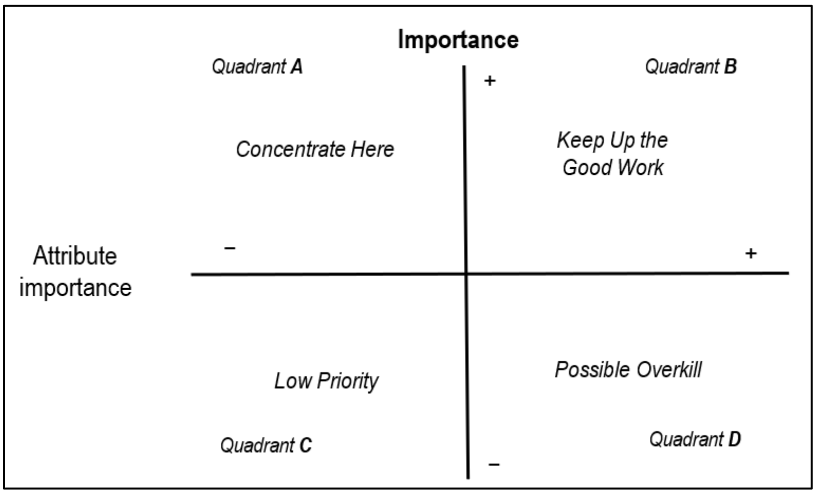
There is debate about how disruptive notifications really are to user attention, or whether such interruptions actually fit with users' desire to interact with their devices. However, there is consensus on the need of the user to be able to operate for the control and real perception of the time spent on devices (Weber et al., 2016), or to block interruptions that can disrupt attention and stimulate hyperactivity. Obviously, the use of apps on mobile devices assumes concession of data, and this requires us to analyze the digital sustainability and learning projection of educational apps, and the correct selection of digital resources for use by teacher and student, from an ethical and sustainable perspective.

2. METHOD

A structural equations model methodology was used to conduct the importance-performance analysis (IPA) (Martilla & James, 1977). In this sense, IPA can benefit the design of educational apps in a sustainable, training-focused way. Figure 1 shows IPA's four quadrants of representation.

Figure 1.

Importance Performance Analysis Matrix.



Note: Adapted from Martilla and James (1977).

The approach adopted in this research was formulated according to the following formula:

$$Vos \sum_{i=1}^{n} I_i V_i$$

where *Vos* is the global evaluation of the app in terms of digital sustainability.

I is the importance attached to each attribute of digital sustainability by the teachers:

V is the evaluation that each attribute receives;

n is the number of attributes that constitutes the digital sustainability setting.

Based on this model, we were able to obtain an indirect measure of the elements of digital sustainability that encourage or discourage the adoption of educational apps to complement the development of the teaching-learning processes by teachers in primary education.

2.1. Participants

The study sample consisted of 212 primary Spanish teachers from all the autonomous communities in Spain (n=17): 32.1% men and 67.9% women. Of these teachers, 38.7%. The mean age of participants was about 34 (mean=33.14, standard deviation=2.41). A purposive non-probability sampling method (respondent-driven sampling) was used based on teachers who have used at least one educational app inside or outside the classroom to support their students' learning, so they have experience in the educational use of the app(s). To avoid selection bias, responses from 16 Spanish autonomous communities were obtained.

2.2. Instrument and variables

Data were collected from September 1st and October 21st (2021). The questionnaire used was designed to be completed online by the teachers, who had to provide prior informed consent, under the Spanish Research Project (GAUBI-RTI2018-099764-B-100). The sample was heterogeneous to boost the study's external statistical validity, with participants teaching in different courses corresponding to students from 6 to 12 years old. The questionnaire was sent to the official email accounts of different schools and high schools. The questionnaire contained 15 items grouped as three latent variables. The teachers had to respond to each item by scoring it on a 1-7 scale, 1 meaning "totally disagree" and 7 "totally agree". The items selected were adapted from works by a range of authors (Table 1) and from previous research activities using focus groups with a selection of teachers using gamified apps

Table 1

Selected dimensions and attributes for sustainability measurement.

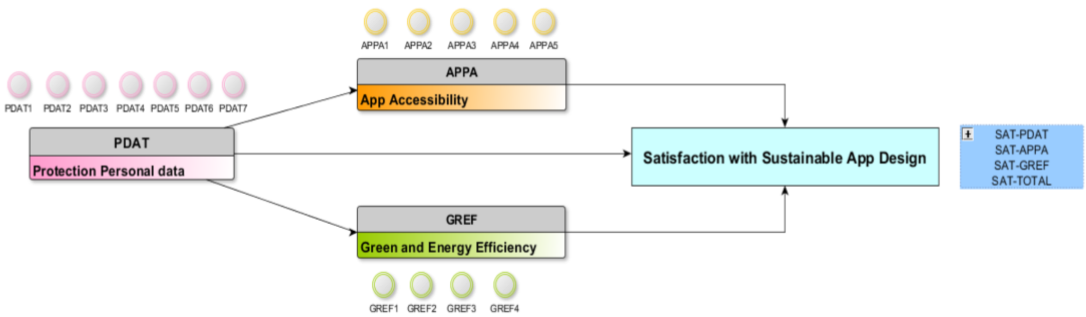
Dimension	Variable	Item	Scientific Literature
PDAT Protection Personal data	PDAT1 PDAT2 PDAT3 PDAT4 PDAT5 PDAT6 PDAT7	1. App informs on the protection of personal data. 2. App explains why it asks for permission 3. App applies an efficient cache policy. 4. App optimize the use of location services. 5. App makes decision reversal easily. 6. App promotes a safe, flexible, and collaborative learning environment. 7. App guarantees transparency (algorithms and processes).	Parsons (2021) Regulation (EU) 2016/679 Willis et al. (2016)

Dimension	Variable	Item	Scientific Literature
EACC Equal access	EACC1 EACC2 EACC3 EACC4 EACC5	8. App design ensures that everybody has access to all functionalities. 9. App optimizes media and images. 10. App implements Zoom/Magnification (resize text). 11. App is designed in a consistent layout. 12. App allows keyboard control for touchscreen devices.	Patch et al. (2015) Directive 2016/2102
GREF Green, Energy Efficiency	GREF1 GREF2 GREF3	13. App uses a green hosting provider. 14. App follows energy efficiency. 15. App allows to adapt the use of timers and notifications.	Greenpeace (2010) Liu et al. (2015) Weber et al. (2016)

In addition to these items, the data on importance were obtained by applying a structural equations model. This structural equation model is based on the principle that the characteristics related to digital sustainability ("Protection of Personal Data", "App Accesibility" and "Green and Energy Effiency") have a direct effect on the satisfaction of teachers when using or recommending educational apps in the teaching-learning processes. This equation model was calculated with the AMOS software.

Figure 2

Model of structural equations specified for the derivation of the importance of attributes.



First, an analysis of the data was carried out to test the validity and reliability of the questionnaire. For this, the Cronbach α coefficient, the Composite Reliability (CR) and the average variance extracted (AVE) were calculated in order to verify the constructs' convergent validity. Finally, the structural model's fitness indices were analyzed and the importance-performance analysis (IPA) was conducted.

3. RESULTS

Prior to structural equation modeling, an analysis of the data was carried out to test the validity and reliability of the scales. The Cronbach Alpha coefficient was above 0.8 and the Kaiser-Meyer index exceeded 0.77. Factor analysis yielded seven factors with the varimax rotation method, thus confirming the validity of the questionnaire. For validity, both convergent and discriminant validity were analyzed, with the results shown in Tables 2 and 3.

Table 2

Standardized estimations.

Factors			λ	Cronbach's α	CR (Composite Reability)	AVE
Protection Personal Data				0.923	0.944	0.881
PDAT1	←	PDAT	0.934			
PDAT2	←	PDAT	0.889			
PDAT3	←	PDAT	0.921			
PDAT4	←	PDAT	0.896			
PDAT5	←	PDAT	0.878			
PDAT6	←	PDAT	0.923			
PDAT7	←	PDAT	0.899			
App Accessibility				0.833	0.901	0.811
APPA1	←	APPA	0.887			
APPA2	←	APPA	0.900			
APPA3	←	APPA	0.812			
APPA4	←	APPA	0.834			
APPA5	←	APPA	0.889			
Green and Energy Efficiency				0.901	0.876	0.803
GREF1	←	GREF	0.865			
GREF2	←	GREF	0.815			
GREF3	←	GREF	0.825			
Satisfaction				0.816	0.887	0.799
SAT1	←	SAT	0.811			
SAT2	←	SAT	0.810			
SAT3	←	SAT	0.857			

Table 2 shows that the reliability of the items was 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 confirmed the reliability of the constructs. Table 2 also shows that the average variance extracted (AVE) was above 0.5, which verifies the constructs' convergent validity. Table 3 presents the results for discriminant validity. For this, the correlation matrix between the constructs was calculated, which confirmed that the correlations were lower than the AVE square root.

Table 3.

Discriminant validity of measures.

	PDAT	APPA	GREF	SAT
PDAT	**0.891**			
EACC	0.721	**0.719**		
GREF	0.711	0.790	**0.798**	
SAT	0.772	0.821	0.723	**0.901**

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

It was observed that all correlations between the constructs amounted for less than the corresponding AVE values for each construct, thus confirming that the factors measured different concepts. Table 4 reflects that all the coefficients are significant at a significance level of 1%. On the other hand, the multiple squared correlations obtained were all greater than 0.3, so that with these two conditions the nomological or predictive validity was verified.

Table 4

Parameter estimates.

Relation			Estimate	S.E.	C.R.	Standardized estimate	*p*
APPA	←	PDAT	0.618	0.061	16.761	0.556	***
GREF	←	PDAT	0.413	0.043	14.650	0.811	***
SAT	←	GREF	0.643	0.113	10.101	0.663	***
SAT	←	APPA	0.556	0.071	9.782	0.623	***
SAT	←	PDAT	0.673	0.065	8.221	0.587	***
PDAT1	←	PDAT	1			0.934	
PDAT2	←	PDAT	1.021	0.101	23.101	0.889	***
PDAT3	←	PDAT	0.861	0.041	21.214	0.921	***
PDAT4	←	PDAT	0.867	0.076	22.002	0.896	***
PDAT5	←	PDAT	0.831	0.067	23.111	0.878	***
PDAT6	←	PDAT	0.833	0.102	25.567	0.923	***
PDAT7	←	PDAT	0.868	0.031	21.456	0.899	***
APPA1	←	EACC	1			0.887	
APPA2	←	EACC	1.213	0.054	15.621	0.900	***
APPA3	←	EACC	1.311	0.045	14.105	0.812	***
APPA4	←	EACC	0.901	0.111	18.213	0.834	***
APPA5	←	EACC	1.219	0.068	14.132	0.889	***
GREF1	←	GREF	1			0.865	
GREF2	←	GREF	0.835	0.063	18.109	0.815	***
GREF3	←	GREF	1.102	0.061	16.741	0.825	***
GREF4	←	GREF	0.881	0.071	16.049	0.865	***
SAT1	←	SAT	1			0.811	
SAT2	←	SAT	1.021	0.033	31.211	0.810	***
SAT3	←	SAT	1.122	0.029	30.002	0.857	***

Finally, Table 5 presents the values of the structural model's fitness indices. All the measures fell within the established limits, which confirmed the data's goodness of fit.

Table 5

Fit indices for the structural equations model.

Fit index	Actual
χ^2	334.118*
df	1.851
Goodness-of-fit index (GFI)	.812
Adjusted goodness-of-fit-index (AGFI)	.811
Comparative fit index (CFI)	.055
Root mean square error of approximation (RMSEA)	.061
Normed fit index (NFI)	.901
Non-normed fit index (NNFI)	.930
Parsimony normed fit index (PNFI)	.791

All the measures had values within the limits that allow us to confirm the data's goodness of fit. The importance of each attribute derived from the total of the effects of each latent variable on the teachers' total perception (satisfaction) (Allen et al. 2020). (Table 6).

Table 6

Predictor variables.

	Direct effect	Indirect effect	Total effect
PDAT	0.000	0.771	0.771
EACC	0.698	0.000	0.698
GREF	0.000	0.623	0.623

We considered a normalization of between 0.00 and 1.00 on the lowest and highest values in order to obtain the normalized values (Table 7).

Table 7

Importance, satisfaction and discrepancies.

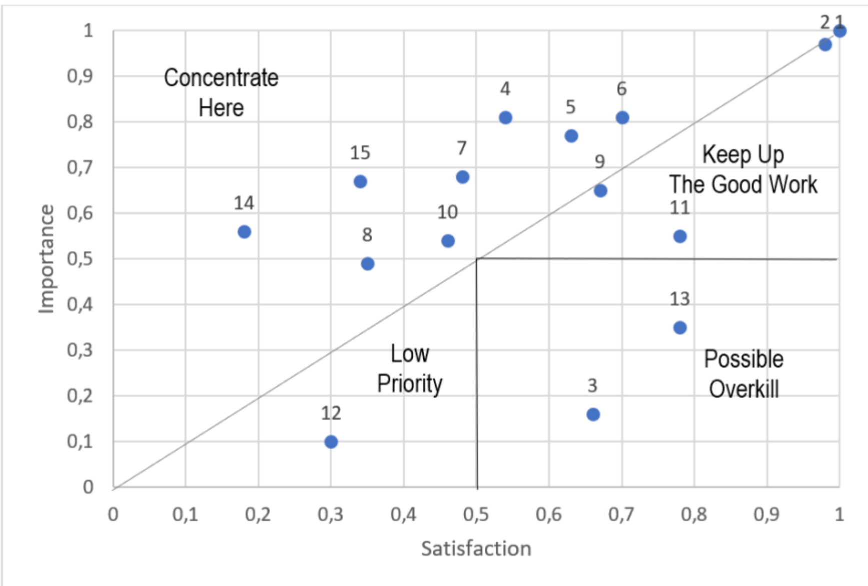
#	Attributes	Import.	Satis.	Norm. Import.	Norm. Satis.	Discrep.
1	App informs on the protection of personal data.	0.64	4.50	1	1	0.00
2	App explains why it asks for permission.	0.61	4.11	0.97	0.98	0.00
3	App applies an efficient cache policy.	0.52	4.02	0.16	0.66	-0.08
4	App optimizes the use of location services.	0.50	3.91	0.81	0.54	0.09
5	App makes decision reversal easyly.	0.58	4.21	0.77	0.63	0.12
6	App promotes a safe. flexible and collaborative learning environment.	0.65	4.83	0.81	0.7	0.11
7	App guarantees transparency (algorithms and processes).	0.56	4.02	0.68	0.48	0.20
8	App design ensures that everybody has access to all functionalities.	0.50	3.97	0.49	0.35	0.10
9	App optimizes media and images.	0.55	2.99	0.65	0.67	0.12
10	App implements Zoom/Magnification (resize text).	0.43	3.38	0.54	0.46	0.22
11	App is designed in a consistent layout.	0.49	2.71	0.55	0.78	-0.11
12	App allows keyboard control for touchscreen devices.	0.38	3.88	0.1	0.3	-0.13
13	App uses a green hosting provider.	0.40	4.12	0.35	0.78	-0.13
14	App follows energy efficiency.	0.52	4.38	0.56	0.18	0.08
15	App allows to adapt the use of timers and notifications.	0.58	4.17	0.67	0.34	0.10

Note: Import. (importance) / Satis. (Satisfaction) / Norm. Import. (Normalized Importance) / Norm. Satis. (Normalized Importance) / Discrep. (Discrepancies).

We used a combination of classic and diagonal models to represent the results (Abalo et al., 2006). The positive discrepancy is represented as “concentrate on this” and “keep up the good work”, the negative discrepancies are below the diagonal: “low priority” and “possible overkill” (Figure 3).

Figure 3

Representation of combined classic and diagonal models.



Results in Figure 3 show that the attributes most in need of improvement were: (1) Inform on the protection of personal data. (2) Explain why the app asks for permission. (3) Optimize the use of location services (only when it is necessary, and it is explained the reason). (4) Make decisions reversal easily. (5) Promote a safe flexible and collaborative learning environment. (6) Guarantee transparency (algorithms and processes). (7) Ensure that everybody has access to all functionalities. (8) Implement Zoom/Magnification (resize text). (9) Allow to adapt the use of timers and notifications and (10) Follow energy efficiency. The "Possible overkill" was concentrated in two attributes (1) Apply an efficient cache policy and (2) Use a green hosting provider. Finally, there was only one attribute in "Low priority" quadrant: (1) Allow keyboard control for touchscreen devices.

4. DISCUSSION AND CONCLUSIONS

The results of this study showed that teachers perceived various elements of digital sustainability that require attention for learning apps to be used in a safe and ethical way as a support or complement to the teaching-learning processes involving young students. Four areas of digital sustainability were identified as unlikely to ensure robust educational and sustainable use of an app inside and outside the classroom. These included elements that guarantee safe and transparent use of data and algorithms, and safeguards on user permission for apps to operate. Teachers also examined whether the app design facilitated functional diversity students' use, and whether it generated safe and collaborative environments for students to work in. Teachers considered that aspects related to energy efficiency, such as efficient cache management and use of a green service provider, were of lesser importance.

Regarding the results on "Safety and ethics in data protection" teachers strongly support the idea of guaranteeing greater transparency in the processes and algorithms used in data treatment. In this sense, four attributes must be preserved: (1) Inform on the protection of personal data. (2) Explain why the app asks for permission. (3) Optimize the use of location services (only when it is necessary, and the reason is explained) and (4) Make decisions reversal easily. The scientific literature has identified that privacy policies have been shown to be inadequate in promoting transparency and personal control (Liccardi et al., 2013). Apps developers and providers frequently fail to include their privacy policies on the interfaces and fail to address the complexity involved in data processing (Liccardi et al., 2013). These authors state that although data gathering processes in Europe and the USA are central to the privacy architecture, the major platforms continually skirt around such regulations precisely because of the lack of transparency in the data capturing process (Kollnig et al., 2022).

In this sense, the analysis of free online apps for children by Reyes et al. (2018) revealed that most products failed to comply with data protection regulations, rendering the personal and identificatory information that children generate when using an app unprotected, in violation of EU, UK and US law (Kollnig et al., 2022). Neither is greater data protection found in paid-for apps (Han et al., 2019). As Livingstone, Stoilova and Nandagiri (2019, p.1-2) establish: "The invasive tactics used by marketers to collect personal information from children have aroused data privacy and security concerns particularly relating to children's ability to understand and consent to such datafication and the need for parental approval and supervision, especially for the youngest internet users".

Alenezi and Almommani (2017) made a comprehensive analysis of the permissions attached to learning apps and found that 80% sought more permissions, accidentally or intentionally, than were necessary for the correct functioning of the app. The solution offered by the authors was to "educate" users by informing them of what giving permission entails before installing an app, to show which permissions are enacted while they use the app, and whether requiring user permission is justified. This idea is reflected in the generation of models and assistance for questions of privacy (Lin et al., 2014; Liu et al., 2005, Vázquez-Cano, 2021). They can determine the real purpose behind an app's request for user permission and help the user to distinguish between those that enable the app to function and those aimed at harvesting personal information, so the user can act accordingly (van der Hof, 2016).

Learning analytics are a clear example of the permissiveness surrounding uncontrolled data concession that undermines attempts to improve user experience with the apps (Parsons, 2021), evidencing a clear breach between technological advances and ethics in technological education. This issue ought to be treated more seriously, as it is in Germany or Rumania, where sophisticated verification mechanisms allow parents to give consent for the use of an app by their children, such as applying biometric information (European Union, 2021). Another issue that calls for greater transparency is why apps need to seek various types of permission (e.g.: permission to access location). In general, the user cannot easily access or modify terms and conditions for app use, due to lack of knowledge, difficulty, lack of clarity in the content or fear of not being able to use all the app's functionalities by declining to accept certain conditions (Liccardi et al., 2013). It is also true that the number of decisions a user needs to take on privacy and permission is burdensome (Liu et al., 2005) and few users are prepared to properly evaluate the small print (Liccardi et al., 2013).

Regarding privacy, it would make sense for users to be informed more clearly about how they can modify preferences at any moment during app use, to enable them to have greater control over the privacy of their data, and those of any minors under their tutelage. According to Liccardi, Pato, and Weitzner (2013), the platforms that distribute apps should change the operational design and policies to facilitate data privacy before an app can be installed. This difficulty extends to apps for children which, far from adapting the information to a young audience in order to ensure standards of transparency, merely offer the same complex tedious explanations as those aimed at the general public (Milkaite & Lievens, 2020).

The results also showed the need for a boost to safe and flexible collaborative learning spaces. Collaboration is a key competence for 21st century education (OECD, 2005), and teaching professionals understand that collaborative learning requires striking a balance between the proposal of structured activities and providing spaces to encourage spontaneous collaborative interactions (Hämäläinen & Vähäsantanen, 2011, Sáez-López et al., 2022). The study revealed three factors (pedagogical, technological and logistical) to support collaboration in educational settings (Hämäläinen & Vähäsantanen, 2011).

In our study, the main barriers to technology-mediated collaboration in school contexts related to the design of apps, which was often found to lack collaborative elements while providing elements to help monitor student progress. App design should include tasks that foment collaboration such as negotiation, planning, communication and organization, and provide related experiences that can guide educators (Araujo & Carvalho, 2017). This is currently related to the need to promote competency learning in collaborative groups based on learning situations (Vázquez-Cano, 2022).

Accessibility, understood as the ability to interact easily and intuitively with the physical and logical controls of the app (Acosta-Vargas et al., 2021), was also considered by teachers as an issue to be improved. Nowadays there are guidelines to determine levels of accessibility, the most authoritative being the Web Content Accesibility Guidelines (WCAG) (WCAG) (Acosta-Vargas et al., 2021; Patch et al., 2015). They are aimed to encourage the development of content that is “perceivable”, “operable”, “understandable” and “robust” (POUR), with specific indicators for each of these categories. The study by Balaji and Kuppusamy (2006) discovered numerous accessibility problems for users, including poor visibility, which could be improved by adaptable text and options to change text font and size, which was also an aspect for improvement indicted by teachers in our study.

Regarding the latent variable “green, energy efficiency”, it contained two indicators which, according to the teachers surveyed, are being neglected and which relate to compliance with the principles of energy efficiency and handling of notifications and timers. Energy efficiency is the responsibility of both the user who needs to develop efficient usage habits, as well as that of the manufacturer, who should constantly strive to develop updates that enhance sustainable energy use. In the educational context, the sustainable use of apps must involve promoting responsible behaviours by encouraging user participation in the “green” culture, but also include ways to avoid unwanted notifications that can disrupt students’ usage of the app by providing control tools (Weber et al., 2016).

The results of this study also referred to efficient cache policies, the use of an ecological storage provider and keyboard activation on tactile devices, issues that were not deemed so relevant in terms of ensuring the safe and ethical use of apps in the classroom. The perspective of users, experts and professionals charged with safely and effectively implementing learning apps for use with young children must continue to evaluate these resources, because the solutions that arise from specific needs aim at continuous improvement of digital sustainability in our classrooms. This aspect relates to the SDGoal 7: “Ensure access to affordable, reliable, sustainable and modern energy for all”.

As soon as digital devices and apps are adopted in the classroom, it is essential for teachers, students and families to consolidate actions and attitudes that promote safe, ethical and sustainable use of devices (Vázquez-Cano et al., 2020). This means that the feedback procedures based on learning analytics must be robust to guarantee the protection of these rights on the servers that encrypt data anonymously. It is also important that the apps promote safe collaborative learning and enable students with functional diversity to operate the apps in the same way as any other student. One aspect that requires continued work both inside and outside the classroom is environmental awareness. The teachers in this study perceived no risk in elements related to green hosting or optimizing energy savings. Both dimensions comply with sustainable development objectives and should be visible in the school curriculum and in the competences that teachers and families need to acquire when using app and mobile digital devices.

Ethical Standards and Informed Consent

Informed consent was obtained from all participants for being included in the study. As the participants in this study belong to 16 Spanish autonomous communities, the informed consent was obtained by each educational administration (Number: GAUBIPRO 4150516/6) and from all participants for being included in the study.

Limitations and future research

In this study, a purposive non-probability sampling method (respondent-driven sampling) has been carried out. It has been based on teachers who have used at least one educational app inside or outside the classroom to support their students' learning. This approach limits the vision of teachers who have not used an educational app and the difficulties that inhibit its use in or outside the classroom. For future studies, a contrastive analysis should be considered between the perception of teachers with experience in the use of educational apps with those teachers new to the use of digital devices in order to detect those aspects that can improve the adoption of ubiquitous and mobile strategies in the teaching processes. Likewise, future studies should focus on the didactic functionality of the apps depending on the subject in which they are applied.

Acknowledgments

This research has been developed with the support of the I+D+I Project entitled: ‘’Gamification and ubiquitous learning in Primary Education. Development of a map of teaching, learning and parental competences and resources “GAUBI”. (RTI2018-099764-B-100) (MICINN/FEDER) financed by FEDER (European Regional Development Fund) and Ministry of Science, Innovation and Universities of Spain.

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To cite this article:

Vázquez-Cano, E., Quero-Gervilla, M., Díez-Arcón, P., & Pascual-Moscoso, C. (2023). Analysis of digital sustainability factors in the adoption of learning apps in primary and secondary education. *Edutec. Revista Electrónica de Tecnología Educativa*, (83), 24-40. https://doi.org/10.21556/edutec.2023.83.2715