Game-based Learning Assessment: Quantifying Educational Efficacy of the EDURINO App

Ning Ding[1 2], Nastassia Sidarto[2], Irene Klemm[2], Franziska Meyer[2] and Nicola Clayton[1]
[1] Department of Psychology, University of Cambridge, Cambridge, UK
[2] EDURINO GmbH, Munich, Germany

ning@edurino.com/nd422@cam.ac.uk
nastassia@edurino.com
irene@edurino.com
franziska@edurino.com
nsc22@cam.ac.uk

Abstract: Assessing the potential and efficacy of educational apps is crucial for parents, educators and EdTech stakeholders. This paper presents evidence from two quantitative studies on EDURINO, a game-based learning app targeting children aged 4-8. It features seven subject areas and is designed to be used with an ergonomic pen that facilitates fine motor skill development and pen-holding gesture. In Study 1, parents (N = 45) used a validated index (Kolak et al., 2021) to evaluate the app's educational potential across 10 features. In study 2, a larger cohort of parents (N = 235) reported on their children's school readiness and fine motor skills. Specifically, we adapted the Brief Early Skills and Support Index (BESSI) to measure changes in behaviours and cognition. We also included items from the Child Development Inventory and Ages and Stages Questionnaire to assess fine motor skills. Study 1 results indicated high ratings for EDURINO's meaningful learning and social interactions, but lower for adaptive learning. Parents' evaluation of EDURINO did not differ by child gender, age, or subject area, but varied with parental education level (the higher the educational attainment, the lower the ratings). Study 2 found that there were statistically significant improvements in children's behavioural and cognitive development as well as fine motor skills after playing EDURINO. Changes in those areas were independent of children's age, gender, and subject area. Moreover, children's improvements were positively correlated with the length of playing. However parental engagement level influenced and was negatively associated with children's improvements in EDURINO targeted area. Overall, these studies provide evidence on EDURINO's efficacy while highlighting the necessity for improvement with personalised and adaptive learning. The importance of transparency and collaboration between academia and industry, along with the influence of demographic factors are discussed.

Keywords: Game-based Learning, Educational Technology, App Evaluation, Child Development, Fine Motor Skills, Efficacy Study

1. Introduction

Touchscreen mobile devices, such as smartphones and tablets, have become internationally ubiquitous for young children. There has been increasing effort and popularity in research and industry to understand, design and test digital games and activities (Kabali et al., 2015). Recommendations have also shifted from preventing screen time holistically to more constructive views of providing meaningful content to facilitate learning outcomes (Hirsh-Pasek et al., 2015). Indeed, educational mobile applications, shortened as 'educational apps', have witnessed an exponential growth followed by the rising concerns over their quality, efficacy, and influence on child development (Common Sense Media, 2013). Recent meta-analysis has reported clear learning benefits for early academic skills, particularly in young children's mathematics and literacy knowledge (Griffith et al., 2020). Moreover, non-app related factors have been shown to impact the efficacy of educational apps; in terms of demographics, preschool children and those from lower socioeconomic backgrounds seem to benefit the most (Common Sense Media, 2013; Kim et al., 2021). Research has also considered the way in which children engage with digital learning and highlighted the advantage of parent-child co-use of digital media (Taylor et al., 2023).

Children acquire, practice and perfect their cognitive and learning development through play and experts of game-based learning have argued that conventional educational principles can and should be applied to the digital environment (Bang et al., 2023). Notably, a key component in both traditional and digital learning is to support and adapt for children's 'zone of proximal development' (ZPD, Vygotsky, 1978) where task difficulty should be above their current capacity but within reach for progress (Plass & Pawar, 2020). In digital environment, open-ended play context provides the learning structure where children are able to explore content freely (Hatzigianni, 2018). Despite the differences in how learning materials are presented and communicated, educational apps should, in principle, provide similar experiences as to traditional pedagogy settings where there are opportunities for tailored feedbacks and interactions (Mulliner & Tucker, 2017).

EDURINO, developed by an EdTech start-up based in Munich, is an educational app for children aged 4-8 and it aims to support school readiness and fine motor skills. Currently, there are seven subject areas, namely Mathematics, Literacy, Nature & Science, Human Body Biology, Coding, Social Emotion Learning and Creative Arts, with content available in both German and English. A unique feature of EDURINO is the use of a stylus pen. Pen-holding gesture has been associated with early writing ability (Rowe, 2019), which inspired the development of EDURINO's 'magic pen' (Figure 1). The ergonomic pen supports different pen-holding grips and was specifically designed to train children's handwriting gesture and fine motor skills. In terms of learning content, EDURINO has holistic as well as detailed scope and sequences of learning objectives, which are in line with country-specific curriculum, for example the Early Years Foundation Stage (EYFS) statutory framework in the UK. EDURINO's content structure is also informed by pedagogical theories of learning trajectories (Simon, 1995) and mastery/competent-based learning approach (Plass & Pawar, 2020). More importantly, for better engagement and learning outcomes, all materials are presented in a playful and engaging digital platform with clear context and narratives (Fisch et al., 2012). After the initial steps of account registration and setting up parental control features, children can explore and play EDURINO games in a self-guided way without parental engagement and guidance.

The overarching aim of the current study was to investigate EDURINO's efficacy and quantify its educational benefits among the target audience (children aged between 4-8). It was also of research and industry's interests to examine the role of players' demographics on the app's efficacy. To this end, we selected a range of demographic and app-related factors that have been identified in the literature. Specifically, we included measures of child age group, child gender, parental education, subject area of EDURINO games, parental engagement style and length of playing. Given it was the first empirical research conducted on EDURINO, the study was exploratory with no specific and prior assumptions. In the current study, first we utilised a quantitative instrument to examine parents' evaluation of the app and content (Study 1); second, we administered a parent-reported survey focusing on the educational benefits of playing EDURINO (Study 2).

Specifically, we explored the following research questions:

1. What is the educational potential of EDURINO, and whether demographic and app-related factors influence parents' evaluation?
2. Do children show any developmental improvements after playing EDURINO, if so whether the educational benefits are affected by any demographic or app-related factors?

Figure 1: EDURINO played on a tablet (left), the magic pen(middle) and screenshot of a Maths game.

2. Method

2.1 Ethics

All procedures performed in Study 1 & 2 were in accordance with the ethical standards of the University of Cambridge Psychology Research Ethics Committee and have been reviewed by the senior author as an independent consultant on the project. All study materials including survey questions were initially prepared in English as the original source of research. The standard translation and back translation procedures were followed to generate the German version. Any discrepancies were resolved between two native German speakers who were fluent in English and had Education degrees (Erkut, 2010). Participants were provided with study information and gave consent online before answering survey questions. After completing the study, they were gifted with a 20% off discount code for EDURINO products.

2.2 Study 1: Assessing EDURINO's Educational Potential With Validated Research Index

2.2.1 Participants and Procedure

Participants were recruited by email invitation from the mailing list of EDURINO's online research community, where commercial users of the app take part in product and design testing. In total, 45 adults (Germany: *N* = 37; UK: *N* =8) completed the online survey which consisted of one evaluation questionnaire and several standardised demographic questions. Data collection took place in January 2024.

2.2.2 Measures

Parents were asked to rate EDURINO's design and content, and the questions were based on a research instrument that specifically developed for assessing educational potential for preschooler's apps (Kolak et al., 2021). The evaluation index included 10 items: learning goal, meaningful learning, solving problems, feedback, social interactions, opportunities for explorations, storyline, quality of language, adjustable content, and app design. Parents were provided with descriptions for each assessment area and rated EDURINO against a 3-point Likert scale (0,1,2) with higher scores indicating higher educational potential. The index was designed for a general audience including caregivers, educators, and researchers and has shown high content validity, internal consistency, and reliability. In terms of demographics (summarised in Table 1), we included questions of country, child age, gender, respondent's relationship to the child, respondent's educational level, as well as which EDURINO figurine(s) children own (each figurine represents one subject area, for example Mika for Maths). Data of some measures was collapsed and merged into one category due to the small number of cases, for example the category of father and grandparents. Other categories were decided based on previous research (age group of players: preschoolers and children of school age) and differences among EDURINO games in terms of learning content and game design.

Table 1. List and percentage breakdown of different categories for each demographical and app-related factor in Study 1.

Factors	Category	
Country	Germany (82.8%)	UK (17.8%)
Parental education	Below Bachelor (57.8%)	Bachelor and above (42.2%)
Relationship to the child	Mother (77.8%)	Father & grandparents (22.2%)
Child gender	Male (42.2%)	Female (57.8%)
Child age group	4-5 years (73.3%)	6-8 years (20.0%)
Subject area	STEM & Literacy (28.9%)	Mix* (71.1%)

*Note. The mix category included all figurines of the STEM & Literacy games, *plus* Yuki for Creative Arts. The Yuki subject is distinctive from the rest because it has the most open-ended play areas with less structured learning content and objectives. We did not list Yuki as a single category by itself due to the small number of cases.

2.2.3 Results

The total scores across 10 items were used to represent the educational potential of apps, and we further divided the questions to reflect two different dimensions, namely 'learning content' and 'app feature'. Specifically, learning content (possible score range 0 - 10) was measured and calculated by the sum of 5 items: learning goal, meaningful learning, solving problems, feedback, and adjustable content. App feature (possible score range 0 - 10) was assessed and summed across 5 items: social interactions, opportunities for explorations, storyline, quality of language, and app design. Table 2 represents the percentages of respondents' rating of EDURINO for each of the items in the evaluation index, as well as the descriptive statistics of learning content, app feature and the overall educational potential.

Table 2: Descriptive statistics of EDURINO's educational potential (N = 45).

Evaluation Area	Rating Scale		
	0	1	2
Learning goal	-	7 (15.6%)	38 (84.4%)
Meaningful learning	-	4 (8.9%)	41 (91.1%)

Evaluation Area	Rating Scale		
Solving problems	-	8 (17.8%)	37 (82.8%)
Feedback	2 (4.4%)	5 (11.1%)	38 (84.4%)
Social interactions	-	4 (8.9%)	41 (91.1%)
Opportunities for explorations	2 (4.4%)	7 (15.6%)	36 (80.0%)
Storyline	-	6 (13.3%)	39 (86.7%)
Quality of Language	-	5 (11.1%)	40 (88.9%)
Adjustable content	6 (13.3%)	12 (26.7%)	27 (60.0%)
App design	-	8 (17.8%)	37 (82.8%)
	Mean	SD	Range
Learning content	8.844	1.461	5 – 10
App feature	9.244	0.981	7 – 10
Educational potential	18.089	1.929	14 – 20

To investigate whether parents' evaluation of EDURINO would differ as a function of demographic and app-related factors, non-parametric Whitney U-tests were performed to examine the influence of country, child gender, child age group, parental education, and subject area of EDURINO. The results revealed that parents' evaluation of EDURINO's overall educational potential and app feature did not vary as a function of any demographic or app-related factors (all *ps* >.05, Table 3). However, when evaluating learning content, across both Germany and the UK, parents whose highest educational attainment were below Bachelor rated EDURINO's learning content more favourably (M = 9.307, SD = 1.049), than those who have completed Bachelor and postgraduate degrees (M = 8.211, SD = 1.718).

Table 3: Whitney U-tests statistics on the effect of demographic and app-related factors on EDURINO evaluation.

	Educational Value	Learning Content	App Feature
Country	*z = -1.119, p = .285*	*z = -.922, p = .405*	*z = -.904, p = .422*
Parental education	*z = -1.780, p = .075*	*z = -2.152, p = .031*	*z = -.053, p = .879*
Child gender	*z = -.048, p = .976*	*z = -.198, p = .857*	*z = .104, p = .928*
Child age group	*z = -.688, p = .491*	*z = -.172, p = .863*	*z = -1.158, p = .247*
Subject area	*z = -.840, p = .401*	*z = -.188, p = .851*	*z = -1.096, p = .273*

2.3 Study 2: Quantifying EDURINO's Educational Benefits for Child Development

2.3.1 Participants and Procedure

Participants were recruited using the same method as in Study 1. In total, 235 adults, all based in Germany, completed the online survey which measured parent-reported educational benefits of playing EDURINO across various developmental areas. Data collection took place in February 2024.

2.3.2 Measure

Specifically, questions used to assess children's behavioural adjustment and language/cognitive development were based on the Brief Early Skills and Support Index (BESSI, Hughes et al., 2015). The BESSI was developed to measure school readiness, therefore a suitable instrument for the current study. Research demonstrated that BESSI was of good reliability, longitudinal stability, and measurement invariance (Hughes et al., 2017). To examine fine motor skills, we further selected questionnaire items from the Child Development Inventory (Ireton, 1992) and the Ages and Stages Questionnaire (Bricker et al., 1999). Each item measured a specific aspect of fine motor movement appropriate for the study sample's age range, such as the ability to play with interlocking puzzles, colour and draw pictures with precise features. Overall, we included 25 questions to measure 3 separate areas of child development, of which 12 tapped into children's behavioural development, 6 measured cognition and language, and 7 focused on fine motor skills. Each question/statement described a specific child behaviour or trait, and parents were asked '*after playing EDURINO*, your child is better at _/show more progress in _?'. Responses were rated against a 5-point Likert scale (5-Strongly Agree, 4-Agree, 3-Neutral, 2-Disagree, 1-Strongly Disagree). Across the 25 questions, 10 were reverse items in which parents were asked "'*after playing EDURINO*,

your child is worse at _?/show more _ (problematic behaviours)' of which responses were reversely coded for analysis following Hughes et al. (2015) scoring instruction.

To measure demographic information, parents were asked to report child age, gender, respondent's relationship to the child, respondent's education attainment, how long the child has played EDURINO (in months), whether the respondent engage with the child while playing EDURINO, and which EDURINO figurine(s) the child own. Similar to Study 1, we further divided demographic information to specific categories, and Table 4 represents the list and percentages of each category.

Table 4: List and percentage breakdown of different categories for each demographic and app-related factor in Study 2.

Factors	Category	
Parental education	Below Bachelor (58.4%)	Bachelor and above (41.6%)
Relationship to the child	Mother (89.3%)	Father & grandparents (10.7%)
Engagement style	No (53%)	Yes (47%)
Child gender	Male (44.5%)	Female (55.5%)
Child age group	4-5 years (74.8%)	6-8 years (25.2%)
Length of playing EDURINO	< 6 months (67.6%)	> 6 months (32.4%)
Subject area	STEM & Literacy (33.3%)	Mix (66.7%)

2.3.3 Results

2.3.3.1 Quantifying the Educational Benefits of Playing EDURINO

Before conducting the formal analysis, we additionally created a composite measure, namely EDURINO targeted area, which was the total score across 4 items that asked about children's development in identifying letters of alphabet, recognising name in print, one-to-one numerical correspondence and song and rhymes. The composite score was a useful additional measure, since it holistically captured the behaviours and traits that the EDURINO app directly aimed at improving, therefore a suitable variable when examining educational efficacy.

In the survey, parents were asked whether children were better/worse for a range of behaviours after playing EDURINO, thus their exact responses on the 5-point Likert scale were taken as the post assessment of EDURINO's efficacy. Although there was no direct measure of the pre-assessment of EDURINO's efficacy, we were able to compute it because of the wording and design of the questions. Notably, parents would have selected the 'Neutral' response in the exact same item before children started playing the app. Therefore, we separately computed the baseline measure for each development area by summing scores representing the 'Neutral' response from corresponding items. As a result, we obtained the following scores as the *baseline* measure for educational efficacy: 36 for behavioural development, 18 for cognitive development, 12 for EDURINO targeted area, and 21 for fine motor development. Normality check was performed and there was homogeneity of variances (all *ps* >.05 for Levene's test). Also, data were normally distributed with no outliers, assessed by boxplot inspection, and comparing the Kurtosis and SE Kurtosis value against with the critical value of 1.98.

To quantify EDURINO's efficacy, we conducted paired t test to investigate whether playing EDURINO have introduced positive educational benefits for children, by comparing parents' initial perception of its efficacy (based on the neutral responses in the survey) with the post assessment of efficacy after children have played the app. Notably, *after playing EDURINO* games, parents reported significant improvements across children's behaviour, cognition/language, fine motor skills and EDURINO targeted area (all *ps* <.001, Table 5, Figure 2).

Table 5: Descriptive statistics of pre & post efficacy of EDURINO and results of paired t-tests with effect sizes.

Assessment area	Mean (SD) of post efficacy	Mean difference (SD) between pre & post	Paired t test
Behaviour	41.871 (5.193)	5.876 (5.193)	*t (233) = 17.309, p <.001, d = 1.132*
Cognition	21.449 (3.864)	3.449 (3.863)	*t (233) = 13.655, p <.001, d = 0.893*
EDURINO targeted	14.889 (2.730)	2.889 (2.730)	*t (233) = 16.185, p <.001, d = 1.058*

Assessment area	Mean (SD) of post efficacy	Mean difference (SD) between pre & post	Paired t test
Fine motor	25.026 (3.693)	4.026 (3.693)	*t (233) = 16.675, p <.001, d = 1.090*

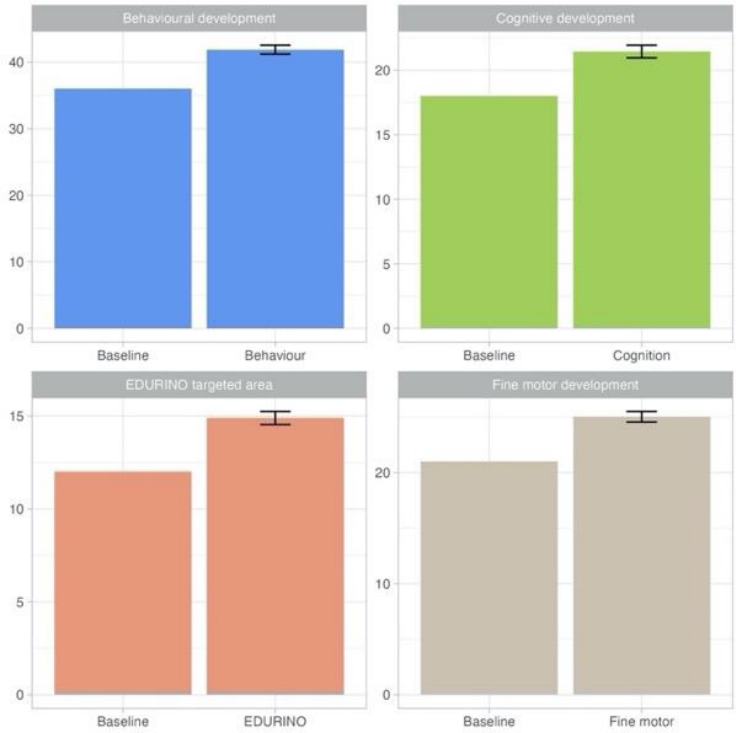

Figure 2: Mean efficacy scores of EDURINO *before* (baseline level, left bar) and *after* playing (right bar) with error bars represents standard deviations. There were no variations in the computed scores of baseline efficacy, thus error bars were omitted.

Second, independent-samples t-tests were conducted to examine the effect of demographic and app-related factors on parents' reported efficacy of EDRUINO across the 4 different development areas (Table 6). Notably, when quantifying EDURINO's educational benefits, parents who did not or rarely engage with children while they play the EDURINO app (*N* = 124) reported *higher* improvements in children's cognitive development (M = 21.99, SD = 3.723; t (232) = 2.305, *p* =.022, *d* = 0.299) and EDURINO targeted area (M = 15.28, SD = 2.649; t (232) = 2.363, *p* =.019, *d* = 0.307), compared to those who often/always engaged with their children (*N* = 110) during the playing session (Cognition: M = 20.84, SD = 3.943; EDURINO targeted area: M = 14.45, SD = 2.765). We also conducted exploratory analysis to test all possible combinations of interaction effects using one-way analyses of variance (ANOVA) and the data met all assumptions. There were no significant interactions between demographic and app-related factors on parents' perceived efficacy of EDURINO on children's development (all *ps* >.05).

2.3.3.2 Examining Correlational Trend of App-usage and Child Development

First, we tested the relationships between the different developmental areas; after controlling for age (measured in year with one decimal place) and child gender, all 4 areas were significantly correlated with each other (all *ps* <.001, table 7), suggesting convergent validity of the measures. Next, we explored the relationships Table 6. Independent samples t-tests on the effect of demographic and app-related factors on parent-reported EDURINO's efficacy.

Factor	Developmental area			
	Cognition	Behaviour	EDURINO targeted	Fine motor
Child age group	t (224) = -.806, *p* =.421	t (224) = .663, *p* =.508	t (224) = -1.018, *p* =.310	t (224) = -.763, *p* =.446
Child gender	t (227) = .914, *p* =.362	t (227) = -.340, *p* =.734	t (227) = 1.252, *p* = .212	t (227) = -.032, *p* = .974

Parental education	t (217) = 1.721, *p* =.087	t (217) = 1.243, *p* =.215	t (217) = 1.916, *p* =.057	t (217) = -.154, *p* =.878
Subject area	t (232) = .394, *p* =.694	t (232) = .044, *p* =.965	t (232) = .237, *p* = .813	t (232) = -.713, *p* =.477
Parental engagement	*t (232) = 2.305, p =.022*	t (t (232) = .311, *p* =.756	*t (232) = 2.363, p =.019*	t (232) = 1.559, *p* =.120
Length of playing	t (220) = -1.686, *p* =.093	t (220) = .600, *p* =.549	t (220) = -1.906, *p* =.058	t (220) = -.983, *p* =.327

Between children's overall improvement and specific skills, and demographic and app-related factors. The majority of the results were non-significant (all *ps* >.05), except for the following. Notably, parents' engagement style was significantly and negatively correlated with the perceived improvements in children's cognitive development (Spearman's correlation: r = -.159, p =.015) and EDURINO targeted area (r = -.165, p =.011), suggesting that the lesser parental involvement during the playing session, the greater improvements children demonstrated (as perceived by parents). In terms of specific skills, children's playing length (measured in month with no decimal places) were significantly and positively correlated with the improvement in print recognition (r = .145, p =.031), numerical one-to-one correspondence (r = .230, p =.011), the ability to draw precise human/body features (r = .142, p =.034), and hand manipulation of folding papers and using scissors (r = .133, p =.048), while significantly and negatively related to children's tendency to interrupt inappropriately at social interactions (r = -.141, p =.036).

Table 7: Partial correlations between different developmental areas after controlling for child age and gender.

	1	2	3	4
1. Cognition	-	.426***	.957***	.566***
2. Behaviour		-	.406***	.593***
3. EDURINO targeted			-	.564***
4. Fine motor				-

Note. *** indicate p <.001, ** indicate p <.01, * indicate p <.05.

3. Discussion

The current research was the first attempt to empirically assess EDURINO's educational efficacy. In Study 1, we adopted a validated evaluation index and EDURINO demonstrated great potential not only in learning content but also with its app feature. In Study 2, parents reported changes in children's school readiness, i.e., behavioural and cognitive development, as well as fine motor skills and the findings suggest that there were significant improvements and benefits after children playing EDRUINO.

In answer to the first research question (Study 1), EDURINO's top 2 strengths were 'meaningful learning' and 'social interactions'. Indeed, games in EDURINO were designed to meet specific learning objectives with clear context, instructions, and learning trajectories (Simon, 1995). The use of physical figurines to unlock the digital learning world is well-received among children. The characters also guide and interact with children during their learning journey, further enhancing the social experiences of playing EDURINO. On the other hand, EDURINO's most glaring limitation was 'adjustable content', also a common challenge across the industry (Callaghan & Reich, 2018). Yet, with the fast-developing AI tool, educational games that tailor content and pace to users' performance are more than ever promising and feasible. Notably, EDURINO's educational potential did not differ among specific user group or subject area, indicated by the non-significant effects of child demographics and app-related factor. Although the evaluation was based on parental ratings only, the findings were insightful and reliable considering the index was developed specifically to be used for a wider audience including parents (Kolak et al., 2021). However, parents' educational level did influence their evaluation of the app; this is important to consider when EDURINO enters markets where there are higher competitions and parents are more familiar with EdTech products. Future study on EDURINO should aim to adopt the multi-informant approach by including researchers and educators in the evaluation process.

Addressing the second research question (Study 2), we measured parent-reported changes in different child developmental areas using items from established instruments (Bricker et al., 1999; Hughes et al., 2015; Ireton,

1992). The results provided empirical evidence to first support and second quantify the efficacy of EDURINO. In percentage terms, children improved by 24.1% in EDURINO targeted areas, 19.2% in fine motor skills, 19.2% for cognitive/language development and 16.3% for behavioural adjustment. The findings suggest that there were holistic educational benefits across multiple developmental areas. Worth highlighting is that demographic and app-related factors did not influence how parents perceive children's changes in their school readiness and fine motor skills, suggesting the educational benefits were evident for all EDURINO users. Moreover, there seems to be some cumulative benefits for playing EDURINO for longer term, indicated by the positive associations between playing length and children's drawing ability, fine motor skills, print recognition and numerical knowledge. Interestingly, in contrary to existing literature (Taylor et al., 2023), parents perceived children's improvements (in EDURINO targeted area) to be higher when they did not engage during the playing session. Additionally, parental engagement style was negatively correlated with improvement in cognition and EDURINO targeted area. EDURINO was introduced to parents as a self-guided/paced app for children with educational games, and this may have influenced their judgment and impression. One possibility is that parents expected and were more likely to identify and report improvements when children engaged with the learning content independently. However, it is vital to recognise that in the current study parents were asked about *changes* in children's behaviour, which was prone to bias and demand characteristics. A more robust research design would use the same assessment items but ask parents to rate children's current level of development at two time points, then report educational efficacy based on the pre-post differences.

4. Strength and Future Research

To date, there has been no investigation on EDURINO's efficacy using research validated tools, therefore the current research adds a novel contribution not only to its internal stakeholders but also provides transparency to parents, educators and EdTech researchers. It also sets an example of collaboration between research and industry since to the best of our knowledge it is the first commercial app to utilise Kolak's educational index. Nevertheless, the current research has several limitations which point to fruitful directions for future studies. First, there was insufficient British respondents in the study sample and future research should aim to recruit equal number of participants from both countries where EDURINO are played. Second, instead of relying on parent report, it's more ideal for efficacy study to directly measure children's literacy, mathematics, and any targeted skills with standardised tasks outside the game context. Training study and randomised control trials would provide the strongest evidence for efficacy.

5. Conclusion

The current research provides first evidence that EDURINO, a game-based learning app for children aged 4-8, can significantly improve young children's school readiness of behavioural adjustment, cognitive and language development as well as fine motor skills. The app demonstrates strong and holistic educational potential with its meaningful and developmentally appropriate learning content and user-friendly app feature. On a broader level, the study not only highlights areas for ongoing refinements to EDURINO but also offers actionable insights to the EdTech industry.

Reference

Bang, H.J., Li, L. and Flynn, K., 2023. Efficacy of an adaptive game-based math learning app to support personalized learning and improve early elementary school students' learning. *Early Childhood Education Journal*, *51*(4), pp.717-732.

Bricker, D., Squires, J., Mounts, L., Potter, L., Nickel, R., Twombly, E. and Farrell, J., 1999. Ages and stages questionnaire. *Baltimore, MD: Paul H. Brookes*.

Callaghan, M.N. and Reich, S.M., 2018. Are educational preschool apps designed to teach? An analysis of the app market. *Learning, Media and Technology*, *43*(3), pp.280-293.

Common Sense Media, 2013. *Zero to Eight: Children's Media Use in America, 2013*.

Erkut, S., 2010. Developing multiple language versions of instruments for intercultural research. *Child development perspectives*, *4*(1), pp.19-24.

Fisher, K., Hirsh-Pasek, K. and Golinkoff, R.M., 2012. Fostering mathematical thinking through playful learning. In *Contemporary debates in childhood education and development* (pp. 81-91). Routledge.

Griffith, S.F., Hagan, M.B., Heymann, P., Heflin, B.H. and Bagner, D.M., 2020. Apps as learning tools: A systematic review. *Pediatrics*, *145*(1).

Hirsh-Pasek, K., Zosh, J.M., Golinkoff, R.M., Gray, J.H., Robb, M.B. and Kaufman, J., 2015. Putting education in "educational" apps: Lessons from the science of learning. *Psychological Science in the Public Interest*, *16*(1), pp.3-34.

Hughes, C., Daly, I., Foley, S., White, N. and Devine, R.T., 2015. Measuring the foundations of school readiness: Introducing a new questionnaire for teachers–The Brief Early Skills and Support Index (BESSI). *British Journal of Educational Psychology*, *85*(3), pp.332-356.

Hughes, C., White, N., Foley, S. and Devine, R.T., 2018. Family support and gains in school readiness: A longitudinal study. *British Journal of Educational Psychology*, *88*(2), pp.284-299.

Ireton, H., 1992. Child development inventory. *Clinical Pediatrics*.

Kabali, H.K., Irigoyen, M.M., Nunez-Davis, R., Budacki, J.G., Mohanty, S.H., Leister, K.P. and Bonner Jr, R.L., 2015. Exposure and use of mobile media devices by young children. *Pediatrics*, *136*(6), pp.1044-1050.

Kim, J., Gilbert, J., Yu, Q. and Gale, C., 2021. Measures matter: A meta-analysis of the effects of educational apps on preschool to grade 3 children's literacy and math skills. *Aera Open*, *7*, p.23328584211004183.

Kolak, J., Norgate, S.H., Monaghan, P. and Taylor, G., 2021. Developing evaluation tools for assessing the educational potential of apps for preschool children in the UK. *Journal of Children and Media*, *15*(3), pp.410-430.

Mulliner, E. and Tucker, M., 2017. Feedback on feedback practice: perceptions of students and academics. *Assessment & Evaluation in Higher Education*, *42*(2), pp.266-288.

Plass, J.L. and Pawar, S., 2020. Toward a taxonomy of adaptivity for learning. *Journal of Research on Technology in Education*, *52*(3), pp.275-300.

Plass, J.L., Homer, B.D. and Kinzer, C.K., 2015. Foundations of game-based learning. *Educational psychologist*, *50*(4), pp.258-283.

Rowe, D.W., 2019. Pointing with a pen: The role of gesture in early childhood writing. *Reading Research Quarterly*, *54*(1), pp.13-39.

Taylor, G., Kolak, J., Norgate, S.H. and Monaghan, P., 2022. Assessing the educational potential and language content of touchscreen apps for preschool children. *Computers and Education Open*, *3*, p.100102.

Taylor, G., Sala, G., Kolak, J., Gerhardstein, P. and Lingwood, J., 2023. Does adult-child co-use during digital media use improve children's learning aged 0-6 years? A systematic review with meta-analysis.