Number Express: A Digital Game to Improve Early Numeracy

Nicoletta Perini[1], Annamaria Porru[2], Korbinian Moeller[1,3,4], Tim Jay[1], Francesco Sella[1]
[1]Department of Mathematics Education, Loughborough University, UK
[2]Department of Developmental Psychology and Socialisation, University of Padova, Italy
[3]Leibniz-Institut Fuer Wissensmedien, Tuebingen, Germany
[4]LEAD Graduate School and Research Network, University of Tuebingen, Germany

n.perini2@lboro.ac.uk
annamariaporru@unipd.it
k.moeller@lboro.ac.uk
t.jay@lboro.ac.uk
f.sella@lboro.ac.uk

Abstract: Early numeracy (including basic skills like counting, order processing, etc.) has repeatedly been observed to predict later scholastic but also vocational prospects. As such, it seems sensible to foster it early on during development. In this article, we describe the development and initial evaluation of *Number Express*, a digital game designed to facilitate numerical skills in pre-and primary school considering the latest evidence from research on order processing. The game consists of a train with six carriages for the player to fill in with numbers in the correct order. The game progresses in difficulty across several levels, moving from smaller to larger numbers and sequences in steps of 2, 5, and 10. Informative feedback helps players in case they respond wrongly. Associating numbers to carriages in the correct order earns the player points, with which they can buy items in a virtual shop, providing additional experience with calculating with money. During the design phase, we sought feedback from researchers, teachers, and an education consultant specialising in the learning and teaching of primary mathematics. Piloting will involve testing the game with a small group of preschool children to evaluate its playability and ease of use and to resolve any remaining technical issues. Additionally, we will gather feedback from children to identify any areas of the game that might be improved or made more engaging. In the next step, the game will be implemented in an intervention study to determine its effectiveness in improving children's early numeracy skills. In case the game proves to be effective in improving children's early numeracy skills, it has the potential to be a valuable tool for educators and parents in supporting their children's numerical development.

Keywords: Digital game, Number ordering, Preschool and primary children, Early numeracy

1. Background

Basic numerical skills are the foundation of more advanced maths skills (Watts et al., 2014) and significantly predict future mathematical learning and scholastic achievement (e.g., Atkinson et al., 2022; Duncan et al., 2020; Davis-Kean et al., 2022; Jordan, Hanich and Kaplan, 2003; Duncan et al., 2006). Around the age of two years, children begin implementing counting routines to learn the cardinal meaning of number words so that “one” represents a set with one item, “two” a set with two items, etc. (Gelman and Gallistel, 1978; Sarnecka, 2015 Sarnecka, Goldman and Slusser, 2015). Children progressively create an association between specific number words and specific numerosities in terms of symbol-magnitude associations. Children also learn that number words reflect ordinal relations depending on their position within the sequence of symbol-to-symbol association; they need to understand the ordinal relations among digits, for example, that 5 comes after 4 and before 6 (Sasanguie and Vos, 2018). Additionally, numbers can be spatially represented in order on a number line where the position of a number provides information about its magnitude and ordinal relation as argued for cartesian axes (Sella et al., 2017).

Not surprisingly, many intervention studies make use of games and activities to consolidate ordinal relations between numbers but also cardinal understanding of number magnitude by fostering children's skills in correctly locating numbers on a number line (e.g., Siegler and Ramani, 2008). With the increasing availability of touch-screen devices such as cell phones, tablets, etc., games and apps have been implemented to facilitate children’s learning, including topics in mathematics and science (Klawe, 1999; Annetta et al., 2009; Sella et al., 2016; Sella et al., 2021). Besides acquiring subject-specific knowledge, such digital games also seem to increase students’ motivation and promote positive attitudes towards learning (e.g., Ke, 2009; Pareto et al., 2011; Crittenden, Biel, and Lovely, 2019). The game “The number Race” (http://www.thenumberrace.com/nr/home.php) is a well-known example of a digital game that was based on solid research evidence (Wilson et al. 2006; Rasanen et al., 2009; Sella et al., 2021) and that has several evidence of its efficacy (Sella et al. 2016). The game supports multiple numerical skills, such as comparing symbolic and non-symbolic numerical quantities, counting, and simple arithmetic. The same research group developed another digital game, Number Catcher, (http://www.thenumbercatcher.com/nc/home.php) to foster basic calculation skills, the base 10 principle and the logic of multidigit numbers. Even though these games support basic numerical skills, they do not specifically target number order skills. There is increasing recent evidence that number order skills are crucial for the development of early numerical skills. Moreover, a search on google scholar with the keywords "number ordering and game" did not bring us back useful results. Therefore, we decided to create a game with a clear theoretical connection to number order.

Considering these background aspects, this manuscript describes the development of the app "Number Express" intended to facilitate early learning of numerical order by requiring children to place numbers in the correct order on a number line.

Here, we will present the main conceptual characteristics of the game and initial feedback on its usability by numerical cognition researchers and educational practitioners before we briefly discuss the next development steps in piloting the game and evaluating its effectiveness in an intervention study.

2. Conceptual Characteristics of the Game

2.1 The Theme and Game's aim

The narrative of Number Express is situated in a train station where the train conductor has to renumber carriages of an incoming train because some carriage numbers have fallen off. The train has six carriages, some of which still have their number label on (serving as reference points for numbering the other carriages), while others do not (reflecting target numbers to be allocated by players).

When starting the game, children first choose between different animal characters representing the train conductor they want to play with and type in their name (see Figure 1).

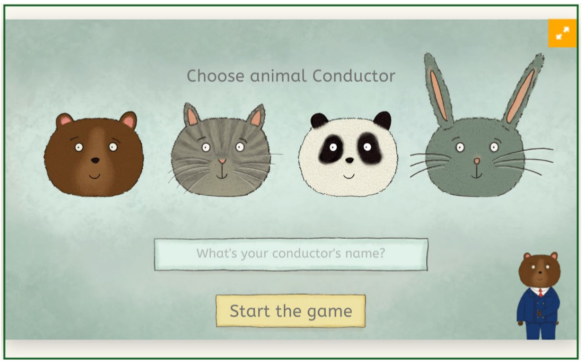


Figure 1: Starting screen to choose the character of the train conductor

Then, the train arrives on the screen, and a target number (to be associated with one of the unlabelled carriages) is shown at the top-left of the screen together with the sound of the respective number word reflecting the association between visual and verbal representations of the respective number (e.g., "four"; Figure 2). The player then has to drag the presented target number to the respective carriage, considering the given numbering on the other carriages as references or simply click on the chosen carriage.

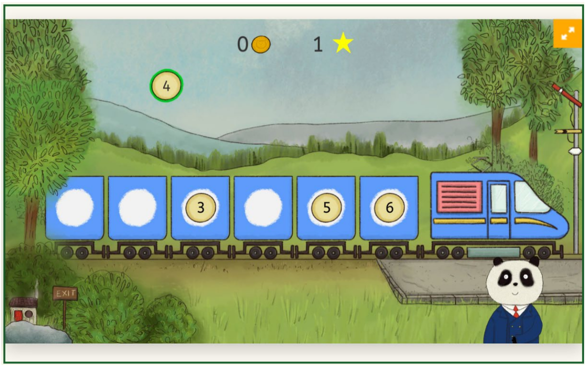


Figure 2: Main gameplay screen showing the train with already numbered carriages. The number 4 with a green circle around it is the number that the player has to put on the right carriage. At the top of the screen, the number of coins earned by the player is given (the number next to the coin image) as well as a number identifying the current level (the number next to the star) and the number of

rounds a player has played within a level (the star indicates that this is the first round played. When the player plays the second round there are two stars on the screen and so on). Each level has five trains. The button "exit" (the sign on the bottom left of the screen) leads the player to exit the game. The button "home" (the little house depicted on the bottom left of the screen) leads the player to the game's homepage

After associating the first target number with a respective carriage, the next one will appear until all carriages are numbered. At that point, the locomotive shines, and children can click on it to make the train leave the station. In case target numbers were associated with carriages to reflect a correct order (e.g., 1, 2, 3, 4, 5, 6 in Figure 2), the train leaves the station and another train appears on the screen. When some of the numbers are not in the correct order, the train does not leave the station and the numbers which are on the wrong carriages will be moved to the top of the screen and informative feedback appears on the screen. If the player put the numbers in the wrong carriages the first feedback that they receive is a visual and verbal message (Good try! Some of the numbers are not in the right place), and then they can try again to put the number on the right carriages. If they put the numbers in the wrong place again they receive the same message and a number line appears under the train. Then, the player can use the number line to copy the position of the numbers (See paragraph 2.3 and Figure 4 for more information on this game's informative feedback). For every train the player makes leave, they are awarded one coin as a virtual incentive. After five trains successfully leave the station, the player will have five coins to spend in a virtual shop (Figure 3) allowing them to buy accessories for the train (e.g., stickers to decorate the train or the possibility to change the shape of the train) and clothes or accessories for the train conductor (e.g., a new outfit, a hat or a toy). To pay in the shop the player can only use the virtual coin earned playing the game. They can also change the train conductor character for free (e.g., panda, bear, cat, and rabbit). Once they are done with their shopping, they can return to playing the game.

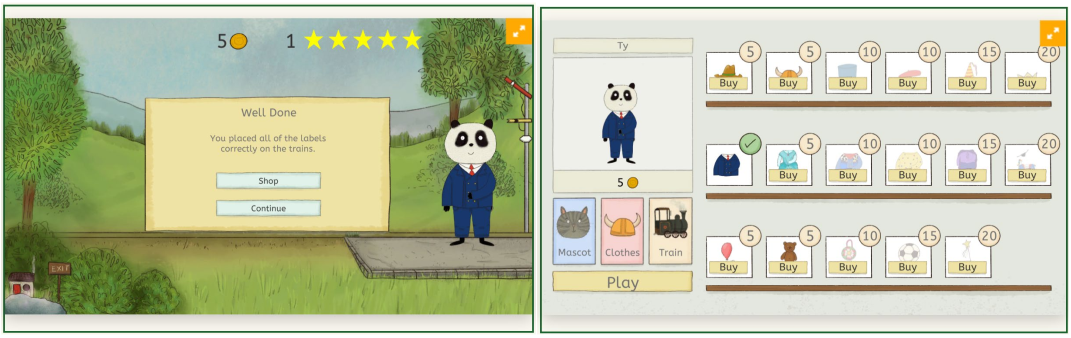


Figure 3: The shop. On the left is the screen where the player can choose to go to the shop or continue playing. In the latter scenario, the player will continue accumulating the coins earned during the game. On the right is the screen of the shop. The player can see their train conductor with their name, and the amount of virtual coins they can spend in the shop. Once they have completed their shopping the amount of money will change accordingly. The button with the label "Clothes" depicted allows the player to see all the goods they can buy for the train conductor. The button with the Mascot depicted allows the player to change the train conductor for free. The button with the Train depicted allows the players to see all the accessories they can buy for the train

2.2 The Levels

The game comes with 118 levels of difficulty, which mainly vary depending on the number range and the respective reference numbers already on the carriages. For instance, level 1 only involves numbers between 1 and 6 with three reference numbers given, whereas level 60 involves numbers between 71 and 76 with only one reference number. Each level involves 5 rounds (5 trains with all the carriages labelled).

It is possible to start the game at seven starting points (Table 1) for levels operating on the same numerical content (i.e., number range, counting in 1s, 2s, decade crossings, etc.) and thus difficulty. The starting points align with the UK Curriculum (Department for Education, 2021) reflecting that during the Early Years Foundation Stage, children up to 5 years (Reception year) should learn to verbally count beyond 20 (reflected by starting point 1), and recognise the pattern of the counting system (e.g. even numbers patterns: 2 ,4, 6,….; odd number patterns: 3, 5, 7,…reflected by starting point 2). Children in Year 1 should learn to count, read and write numbers up to 100 in numerals, count in multiples of 2s, 5s and 10s, as well as identify and represent numbers using pictorial representations, including the number line (Department for Education, 2021). This is reflected in starting points 2 to 7, in which children have to count in multiples of 2s, 5s, and 10s within the number range of up to 119 involving or not involving decade crossings.

This way, the game facilitates children's understanding of the ordinal and spatial relations between numbers (symbol-to-symbol association) by working with number lines while also strengthening the association between Arabic numbers and the corresponding number word (e.g., 10 = "Ten"). Children can learn to count in 2s, 5s, and 10s, while exploring the number range from 1 to 120, including trials involving decade crossings. Additionally, children practise some arithmetic when buying items in the shop although this is not the primary learning goal of the game. All these features make the game align well with the aims of the UK curriculum for the Early Years Foundation Stage and Year 1.

Table 1: Starting Points of the Game

Starting points	Levels	Numerical Content
starting point 1	1-10	Counting in 1s between 1 and 20
starting point 2	11-17	Counting in 2s between 2 and 24
starting point 3	18-24	Counting in 10s between 10 and 120
starting point 4	25-31	Counting in 5s between 5 and 60
starting point 5	32-38	Counting in 2s odd numbers between 1 and 23
starting point 6	39-78	Counting in 1s between 21 and 119 not crossing tens
starting point 7	79-118	Counting in 1s between 27 and 123 crossing tens

2.3 Adapting the levels to players' performance algorithm

Irrespective of the starting point chosen, we implemented an adaptive algorithm to determine the player's progression through the game. The algorithm keeps the player in a zone of optimal challenge by presenting more difficult levels in case of a given number of correct responses and easier levels in case of incorrect responses (see Table 2a and Table 2b for details). An incorrect response is when the player put the number on the wrong carriage. The train will not leave the station unless all the numbers are on the right carriages. There is no time limit for the player to correct their responses. For players that commit two or fewer errors, there is a 10% chance they play rounds on the same level, a 60% chance they go to the very next more difficult level, a 10% chance they go to two levels up and a 5% chance they go three levels up. For players who give two or more incorrect responses, there is a 60% chance they play rounds on the same level, a 25% chance they go to the previous level, a 10% chance they go two levels down and a 5% chance they go three levels down.

Table 2a: The adaptation algorithm in case of ≤ 2 incorrect responses in a round (each level has 5 rounds. The algorithm decides the difficulty of the next round based on the present round player performance.)

In case the player had ≤ 2 incorrect responses (i.e., clicking on the locomotive to leave the station, but numbers were not in the correct order) in the current round, the algorithm will direct the player to a specific level for the next round with the following probabilities.					
Next Level	L-1	L	L+1	L+2	L+3
Percentage of next-level selection	0%	10%	60%	25%	5%

Table 2b: The adaptation algorithm, in case of >2 incorrect responses in a round (each level has 5 rounds. The algorithm decides the difficulty of the next round based on the present round player performance.)

In case, the player had > 2 incorrect responses in the current round, the algorithm would direct them to a specific level for the next round with the following probabilities.					
Next Level	L-3	L-2	L-1	L	L+1
Percentage of next-level selection	5%	10%	25%	60%	0%

2.4 The Motivation Game's Elements

Malone (1980) described three elements that can make a game fun, and increase intrinsic motivation: *challenge*, *fantasy*, and *curiosity* (Malone, 1980). To be motivating, a game needs to present a challenge to the player with goals and uncertain outcomes, that can engage a player's self-esteem. Moreover, fantasy (i.e., a game can stimulate a player's imagination with its story) can make a game more interesting because the game can evoke images of scenarios, situations or objects that can engage the players. Lastly, a game is more engaging if it stimulates players' sensory, and cognitive curiosity, with novel and surprising content. According to Malone's taxonomy, we considered some of these elements when designing the game.

The adaptative algorithm manipulates the difficulty level to keep the player in a constant zone of optimal challenge. Moreover, the algorithm adds a surprise element as children who respond always correctly in a round may suddenly face much more difficult levels. It is important to notice that this surprise of being presented with much more difficult levels does not apply to children who are already struggling with the current level to avoid any frustration. Another element that makes *Number Express* challenging is its *goal.* Number Express's goal is to label the carriages to allow the train to leave the station. When players do this correctly, they earn virtual money to spend in the *shop*¸ which could be considered an additional goal itself. Children's desire to personalize their avatars and thus buy items in the shop could further motivate children to play the game for longer. Moreover, buying items in the shop offers more opportunities for learning mathematics, such as comparing the cost of an item to the money a player has and calculating how much more money is needed to buy a specific item.

In designing this game, we hired a professional graphic designer to create illustrations that can stimulate children's fantasies. We also chose to present shop items that are frequently liked by both boys and girls. The detailed background and the possibility of choosing and naming their character to play the game should also further stimulate children's fantasy and immerse them in the game's narrative.

To stimulate cognitive curiosity, we implemented a *two-stage informative feedback system.* In particular, when the player puts the numbers on carriages in the wrong order, the wrongly ordered number labels move to the top of the screen, and a visual and vocal message appears to inform the player that the indicated order is not correct (i.e., stage 1, see Figure 4, left chart). At this point, the player can associate the numbers with carriages again. In case, the player gets the order wrong again, a number line will appear under the train so they can use it to order the number correctly (i.e., stage 2, see Figure 4, right chart). Stage 2 shall guarantee that all children can place the numbers in the correct order by matching the numbers on the carriages to those on the number line. This feedback provides players, including those struggling with number order, with enough information to order the numbers accurately (Figure 4).

Overall, the game's goal and the adaptative algorithm make the game *challenging* for children. The visual aesthetics and the narrative activate children's *fantasy* of being the train conductor who needs to make the train leave the station. Finally, the two-step informative feedback system gives children enough information to complete the task at hand.

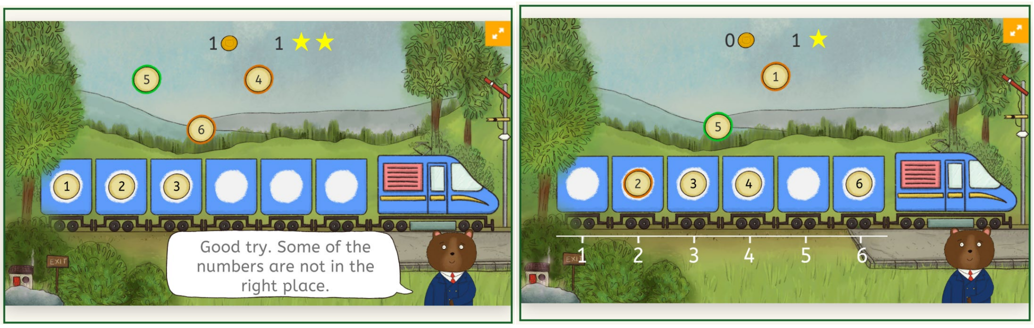


Figure 4: The two-level informative feedback system

3. The Designing of the Game

To design the game Number Express, we reviewed the literature on number ordering skills (Devlin et al., 2022; Sasanguie & Vos, 2018; Sella et al., 2020) and on what makes a digital game engaging for children (Malone, 1980; 1981). We considered studies on the importance of the number line as a tool to spatially represent numbers in number games (e.g., Siegler & Ramani, 2008). This evidence guided us in designing the game. Accordingly, the numbers on the screen are presented in a linear order equidistantly and with numerical magnitude increasing from left to right (i.e., 1-2-3-4…) and we set the levels of difficulty according to the national math goals in the UK. Moreover, we asked a professional graphic designer to create the game scenarios and characters mimicking the style of popular books in nurseries and primary Schools in the UK to ensure the illustrations were familiar to the children and suitable for their age. Finally, the first version of the game was modified according to the received feedback as described in the paragraph "Initial feedback".

4. Evaluation of the Game's Usability

4.1 Initial Feedback

After the first version of the game was prepared, we sought feedback from academic colleagues with a cognitive and pedagogical background, a primary school teacher, and an educational consultant specialising in the teaching of mathematics in Early Years.

They all expressed great interest in the game and evaluated it very positively. They found the game engaging and reported that the learning goals are clear and linked to the UK curriculum.

They suggested offering the possibility to choose the game's level of difficulty and the number range to play with at the beginning (now implemented). The screen with the possibility to select the starting point prevents players from getting bored of playing from the beginning with the easy levels before getting to the challenging ones. Moreover, they suggested presenting larger number intervals from 20 to 120 without crossing the decade before the same intervals are presented with the cross of a decade.

After the piloting phase (see next paragraph), we foresee additional changes to be made before moving to test the effectiveness of the game in a randomised controlled trial.

4.2 Piloting Phase

In the piloting phase, we aim to evaluate the game's usability as "a quality attribute that assesses how easy user interfaces are to use" (Nielsen, 2012, paragraph 1). Accordingly, the usability of a system can have five components (Nielsen, 2012): learnability (e.g., how easy it is for users to accomplish basic tasks the first time they encounter the game), efficiency (e.g., once users have learned the game, how quickly can they perform tasks), memorability (e.g., when users return to the design after a period of not using it, how easily they re-establish proficiency), errors (e.g., how many errors users make, how severe these errors are, and how easily they recover from the errors), and satisfaction (e.g., how pleasant it is to use the game). Following this definition, we developed an observation checklist and an interview-based questionnaire for children to test Number Express's usability.

We plan to recruit children aged 4 to 6. Children will play the game individually on a tablet during regular school hours. Trained research assistants will support children in playing, fill in the observation checklist (Table 3), and, at the end of the game session, ask children a few questions about their user experience (Table 4). The research assistants' interaction with children will be kept to a minimum resembling future user contexts in which teachers will set up the playing session for many children.

The observation checklist will allow us to evaluate the game's learnability, efficiency, and errors. We will not assess memorability during the piloting phase, as children will play only once. We will evaluate players' satisfaction through the interview-based questionnaire (Table 4).

Table 3: The observation checklist

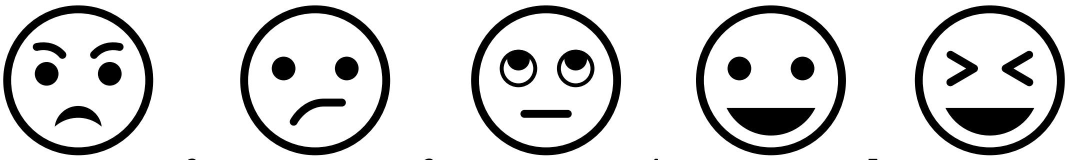
COMPONENTS	INDEXES
Learnability	The child needs to see the video tutorial again or ask the adults for help. How many times?
Effectiveness	The child understands how to start the game.
	The child can select the train conductor.
	The child doesn't need help to write the train conductor's name.
	The child knows how to move the number tag through the screen.
	The train understands how to make the train leave.
	The child understands how to enter the shop.
	The child can buy items in the shop.

COMPONENTS	INDEXES
	The child can come back to the game after having been in the shop.
Error	Frequency of the errors. How many?
	The child knows how to correct themselves.
Efficacy	The number line helps the child to put the number in the right order.

We will evaluate players' satisfaction using an interview based questionnaire (adapted from Ismail et al., 2011).

Table 4: The interview-based questionnaire

Questions to the player
1. The game was fun.
2. The game was easy to play.
3. I like the game characters.
4. I want to play this game again.
5. I would like to play this game at home.
6. I would recommend this to a friend.



1= 2= 3= 4= 5=

5. Conclusion and Future Perspectives

Number Express is a digital game designed to support basic numerical skills in pre-and primary-school children. We designed the game to accommodate crucial aspects of basic numerical development such as ordinality, the spatial representation of numbers (i.e., number line), and counting in 1s, 2s, 5s, and 10s. To facilitate the learning process while playing, we implemented informative feedback which also makes sure that children can correctly complete each trial and gain coins to keep them motivated and avoid frustration. Finally, the possibility to buy accessories in the virtual shops through the coins awarded should also motivate children to keep playing. Additionally, the latter should also entail additional mathematical experience by requiring them to calculate the money to be spent. The final version of the game was developed implementing an iterative design-based research approach where we consulted with expert educational practitioners and incorporated their feedback over several development circles which led to significant changes and adaptations of the original (design) ideas for the game. In the next step of the development process, we aim at testing the game's usability before evaluating its educational effectiveness in a controlled intervention study from which we expect a facilitating effect on children's basic numerical skills. We consider the further development of the game an ongoing process during which we may keep adapting and optimising game elements to maximise its user experience as well as educational effectiveness according to incoming feedback and empirical evidence.

Acknowledgements

We want to thank all colleagues that gave us feedback on the game: Kinga Morsanyi, Tim Jay, Dave Hewitt, Mathematical Cognition Group (Loughborough University), Mathematical Pedagogy Group (Loughborough University), Martin Tillbrook, and Helen Williams.

References

Annetta, L. A., Minogue, J., Holmes, S. Y., & Cheng, M. T. (2009). "Investigating the impact of video games on high school students' engagement and learning about genetics", *Computers and Education*, 53(1), 74–85. Available at: https://doi.org/10.1016/j.compedu.2008.12.020

Atkinson, A. L., Hill, L. J. B., Pettinger, K. J., Wright, J., Hart, A. R., Dickerson, J., & Mon-Williams, M. (2022). "Can holistic school readiness evaluations predict academic achievement and special educational needs status? Evidence from the

Early Years Foundation Stage Profile", *Learning and Instruction*, 77, 101537. Available at: https://doi.org/10.1016/J.LEARNINSTRUC.2021.101537

Crittenden, W. F., Biel, I. K., and Lovely III, W. A. (2019) "Embracing digitalization: Student learning and new technologies" *Journal of marketing education*, *41*(1), 5-14.

Davis-Kean, P. E., Domina, T., Kuhfeld, M., Ellis, A., & Gershoff, E. T. (2022). "It matters how you start: Early numeracy mastery predicts high school math course-taking and college attendance", *Infant and Child Development*, 31(2). Available at: https://doi.org/10.1002/icd.2281

Department for Education (2021). "National curriculum in England: mathematics programmes of study". Available at: https://www.gov.uk/government/publications/national-curriculum-in-england-mathematics-programmes-of-study/national-curriculum-in-england-mathematics-programmes-of-study. Accessed: April 2023.

Department for Education (2021). "Statutory framework for the early years foundation stage". Available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/974907/EYFS_framework_-_March_2021.pdf (Accessed: April 2023)

Devlin, D., Moeller, K., Reynvoet, B., & Sella, F. (2022). "A critical review of number order judgements and arithmetic: What do order verification tasks actually measure?", *Cognitive Development* (Vol. 64). Elsevier Ltd. Available at: https://doi.org/10.1016/j.cogdev.2022.101262

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., Pagani, L., Feinstein, L., Engel, M., Brooks-Gunn, J., Sexton, H., Duckworth, K., Japel, C., Cordray, D., Ginsburg, H., Grissmer, D., Lipsey, M., Raver, C., Sameroff, A., … Zill, N. (2006). "School Readiness and Later Achievement", *Developmental psychology*, 43(6), 1428.

Duncan, R. J., Duncan, G. J., Stanley, L., Aguilar, E., & Halfon, N. (2020). "The kindergarten Early Development Instrument predicts third grade academic proficiency", *Early Childhood Research Quarterly*, 53, 287–300. Available at: https://doi.org/10.1016/J.ECRESQ.2020.05.009

Gelman and Gallistell (1978) *The Child's Understanding of Number*. Cambridge, MA. Harvard University Press.

INSERM-CEA Cognitive Neuroimaging Unit (2004). The number race. Available at: http://www.thenumberrace.com/nr/home.php.

INSERM-CEA Cognitive Neuroimaging Unit (2011). Number catcher. Available at: http://www.thenumbercatcher.com/nc/home.php.

Ismail, M., Diah, N. M., Ahmad, S., Kamal, N. A. M., & Dahari, M. K. M. (2011). "Measuring usability of educational computer games based on the user success rate". *SHUSER 2011 - 2011 International Symposium on Humanities*, in Science and Engineering Research, 56–60. https://doi.org/10.1109/SHUSER.2011.6008500

Jordan, N. C., Hanich, L. B., and Kaplan, D. (2003). "A Longitudinal Study of Mathematical Competencies in Children With Specific Mathematics Difficulties Versus Children With Comorbid Mathematics and Reading Difficulties", *Child Development*, 74(3), 834–850. Available at: https://doi.org/10.1111/1467-8624.00571

Ke, F. (2009). A qualitative meta-analysis of computer games as learning tools. *Handbook of research on effective electronic gaming in education*, 1-32.

Klawe, M. (1999, June). Computer games, education and interfaces: The E-GEMS project. In *Graphics interface* (pp. 36-39).

Malone, T. W. (1980, September) "What makes things fun to learn? Heuristics for designing instructional computer games" in Proceedings of the 3rd ACM SIGSMALL symposium and the first SIGPC symposium on Small systems (pp. 162-169).

Nielsen, J. (2012, January, 3). *Usability: Introduction to Usability*. Available at: https://www.nngroup.com/articles/usability-101-introduction-to-usability/ (Accessed: April 2023).

Pareto, L., Arvemo, T., Dahl, Y., Haake, M., & Gulz, A. (2011). "A teachable-agent arithmetic game's effects on mathematics understanding, attitude and self-efficacy" in *Lecture Notes in Computer Science* (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 6738 LNAI, 247–255. Available at: https://doi.org/10.1007/978-3-642-21869-9_33

Sarnecka, B. W., Goldman, M. C., & Slusser, E. B. (2015). *How counting leads to children's first representations of exact, large numbers*. The Oxford handbook of numerical cognition, 291-309.

Sasanguie, D., and Vos, H. (2018) "About why there is a shift from cardinal to ordinal processing in the association with arithmetic between first and second grade", *Developmental Science*, *21*(5), e12653.

Sella, F., Berteletti, I., Lucangeli, D., & Zorzi, M. (2017) "Preschool children use space, rather than counting, to infer the numerical magnitude of digits: Evidence for a spatial mapping principle", *Cognition*, *158*, 56-67.

Sella, F., Onnivello, S., Lunardon, M., Lanfranchi, S., & Zorzi, M. (2021) "Training basic numerical skills in children with Down syndrome using the computerized game "The Number Race", *Scientific Reports*, *11*(1), 2087.

Sella, F., Tressoldi, P., Lucangeli, D., & Zorzi, M. (2016) "Training numerical skills with the adaptive videogame "The Number Race": A randomized controlled trial on preschoolers", *Trends in Neuroscience and Education*, *5*(1), 20-29.

Siegler, R. S., & Ramani, G. B. (2008). Playing linear numerical board games promotes low-income children's numerical development. *Developmental science*, *11*(5), 655-661.

Watts, T. W., Duncan, G. J., Siegler, R. S., & Davis-Kean, P. E. (2014) "The Groove of Growth: How Early Gains in Math Ability Influence Adolescent Achievement", *Society for Research on Educational Effectiveness*. SREE Spring 2014 Conference Abstract Template.

Wilson, A.J., Dehaene, S., Pinel, P., Revkin, S.K., Cohen, L. and Cohen, D., (2006). Principles underlying the design of" The Number Race", an adaptive computer game for remediation of dyscalculia. *Behavioral and brain functions*, *2*, pp.1-14.