Modification of Mathematical Cognitive Demand with Disruptive Gamification Methods Using Video Games in Schoolchildren Affected by Covid-19

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Abstract

The document reports the effects of the use of video games in the disruptive gamification of the cognitive demand in mathematics of 127 second and third grade students of basic education. They were grouped according to three demand conditions: (a) situation 1 = low; (b) situation 2 = moderate; (c) control group = mixed. All subjects presented some type of Covid-19 sequelae; and situational pairs were compared according to agreement: situation 1 vs. control (first pair); situation 2 vs. control (second pair). The results were collected from a multiple demand test. The abilities to solve tasks of moderate cognitive demand were developed in the subjects who started with a low level of demand, and high-level demand in those who started with a moderate demand. The comparison of the first pair presented more difficulties to achieve improvements in their cognition, unlike the subjects of the second pair.

Keywords

Cognitive reload; Mathematical cognition; Mathematical learning; Video game.

1. Introduction

The didactics of mathematics often tends to be carried out with many obstacles under traditional constructivist teaching systems. This is more noticeable in students who develop mathematics with increasingly complex levels in their schooling. Problems have focused on understanding mathematical meaning and understanding geometry [1, 2, 3]. These problems are usually presented at the beginning of basic education with emphasis on the symbolic representation of quantities and problem solving [4, 5, 6, 7, 8]. The study addresses the cognitive demand in mathematics as the main tool for measuring complex mathematics, in order to demonstrate whether subjects with certain characteristics can overcome them with methods that enable their motivation and block their distractions in solving mathematics.

Current research has considered the main obstacles: distraction, lack of sustained motivation; little creative thinking, and cognitive overload [7, 9, 10, 11]. Consequently, it seeks to demonstrate that by cutting cognitive distractions in mathematics phases of sustained motivation are generated on specific learning processes with certain levels of mathematical demand.

1.1. Disruptive gamification for complex mathematics

The evidence in mixed gamification explains the results that report strategies dedicated to the student using prior knowledge with great agility, with support in the faster interactions that are generated with the teacher [12], with the participation of other competing subjects [13, 14]; and in group interaction due to playful motivation [15, 16, 17, 18, 19]. In this sense, it has been found that the greater the flexibility to guide complex processes, the greater the possibility to reduce

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stress on the mental load of the learner, even promoting more possibilities to self-evaluate and correct themselves in solving mathematics.

Cognitive demand has been proposed as a revealing approach to complex mathematics according to the level of development in the learner [20, 21]. This variable is defined as the set of skills that allow the learner to solve mathematical problems or operations at different levels of difficulty [22, 23], which include the use of basic skills such as reading, inferences, and mental abilities. Short- and long-term cognitive memory intervenes there to contrast previous information with information about operations and problems and provide feasible solutions during a certain development time [20, 21, 23, 24]. It has also been adopted as a learning evaluative approach through the disclosure of proposals for the measurement of gains in the learning average [22]. From this it has been learned that they are beneficial development practices for their learning attitudes, which are intrinsically related to working memory and intelligence for mathematics and computational thinking [23, 24]. Cognitive demand has also been developed as a means of evaluating school performance from representative reasoning in the cognitive performance of school abilities [25]: (a) active memory, (b) problem solving, (c) thought. Faced with the complex task, the student usually recharges his memory in the development of processually complex activities, at least he resorts to help methods in elements external to the mathematical operation such as fun in the face of the challenges of the games, external or internal motivation; and the excitement about the unknown, when the challenges guide their preferences [8, 26].

Some research has been dedicated to questioning the positive reinforcement of gamification or gamification on academic tasks using collaborative gamification [27, 28]. Others identify that challenge-based competitive experience can delay learners' cognitive demand [29, 30]. Thus, the study seeks to verify whether the use of a disruptive method of gamification involving the use of video games can dissipate cognitive overload. This increases sustained motivation in cognitive tasks in two modalities in the area of mathematics: high and low demand. Therefore, the main hypothesis proposes finding positive reactions in the development of mathematics when the student resorts to external distractors that contribute to their motivation for complex learning. Here, the student with a low cognitive level could be motivated and make more diligent attempts at a level of moderate demand thanks to the disruption generated by gamifiers. This system behaves as a reducer of the eventual despair of the students when carrying out tasks with a high level of difficulty, or as a motivator with which it is hoped to divert potential procrastinators from developing in more complex tasks. The development scheme also applies to students who perform regularly but try to reach higher levels of demand pushed by their personal goals of improvement.

The research is based on educational principles based on cognitive integrity for the effectiveness of expected learning in Regular Basic Education in Peru. In this sense, a special sample of students from seven to eight years of age was observed, who were affected by Covid-19 with sequelae that were mostly mild and received virtual classes due to the pandemic in various sections of their corresponding grades. By verifying the gap in mathematics performance with a year of delay in the completion of problems, we sought to contribute to that cognitive integrity to perform effectively in the face of certain curricular demands when promoted to the next higher grade. This suggested finding improvements in mathematics performance by verifying it from a model of cognitive demand until they were able to regulate their learning levels to higher levels. The didactic regulation made it possible to find subjects with a low level who, when confronted with the use of video games in the approach programme, achieved as a minimum criterion a level of response towards moderate levels of mathematical learning. On the other hand, to classify the subjects with a moderate performance in order to make this learning viable with a high demand performance. With this, it was also hypothetically determined that the individuals who passed with a gap in their learning and with health conditions would be included equally in groups that could perform better than them and to whom they could match the learning carried out in their classrooms with the high demand with which they were prepared in the pedagogical approach based on the use of disruptive gamifiers.

2. Method

The investigation is governed according to the quantitative approach with a deductive hypothetical proposal. In this sense, we make comparisons of two types of conversion of mathematical cognitive demand in an experimental model. In this comparison, disruptive gamification acts as an experimental variable. This scheme made it possible to compare two situations differentiated by the effects of this type of gamification: (a) low demand model towards a moderate demand model, (b) moderate demand model towards a high demand model. In the first model, those students who demonstrate low performance in the cognitive demand of mathematics are compared, and were subjected to disruptive gamification to overcome the cognitive demand at a moderate level. In the second model, we verify the effects of gamified disruption in a group that effectively performs in the face of a complex demand after presenting moderate levels of performance.

2.1. Sample and materials

Three groups were classified for comparisons: (a) experimental A (situation 1 $_{(n)}$ = 41), (b) experimental B (situation 2 $_{(n)}$ = 42), (c) control (without gamification $_{(n)}$ = 44). Comparison pairs were formed from these (first pair: situation 1 vs. control group; second pair: situation 2 vs. control group). Regarding the school characteristics, we worked with students of cycle III and IV of basic education. They were all second and third grade students from two educational institutions (one publicly managed and the other private). The sampling was carried out in a non-probabilistic way, corresponding to a mixed selection according to the criteria proposed to assign the students to each group: grade, cycle, age and permanence. Regarding age, the range to be considered was from seven to eight years of age (SD = 0.8 years). Regarding permanence, they had to be students without presenting more than three absences in each school month. However, three additional cases were chosen to exceed the average of 40 subjects in the first situational group. It should be noted that all subjects were assigned to all groups in the most equitable way possible, second and third grade schoolchildren were alternately assigned to situational groups 1, 2 and control. The selectivity of subjects with problems with Covid-19 was carried out according to their clinical condition: (a) students with moderate or mild sequelae, (b) students vaccinated with at least two doses of vaccination. The students' performance up to three months prior to the research was also taken into account, which was based on classifying the students into low (C) and average (B) levels of mathematical performance. The students agreed to participate after sharing the research project with academic tutors and managers in general. However, the parents signed the informed consent to provide the corresponding permission.

Regarding the instrument, the *Arithmetic Problems Test with Multiple Cognitive Demand* [31], was interesting for the researchers, since it responded to the age, school, and social characteristics of our study. The original version presented 16 items structured according to their complexity in dimensions: memorization, procedures without connections, procedures with connections, and doing mathematics. However, we submit the document to the criteria of judges. Thanks to this process, the final version presented 25 items qualified in a dichotomous and polytomous way, in order to preserve the initial evaluative thread of the original authors. According to the needs of this research, the instrument was allowed to calculate three levels: (a) Low cognitive demand, (b) Moderate cognitive demand, (c) High cognitive demand. However, the Test made it possible to measure levels of cognitive demand in the study subjects, although the importance of its use lay in classifying it according to mathematical thinking. This phase also helped to achieve groupings of individuals, more focused on exceeding the level of demand instead of placing them at some level of predominance, which is the central objective of the study. Verifying levels of predominance would not allow comparison of cognitive progress or change when going through the program experience.

The classification was achieved from the contribution of the expert judges in a peer review. A preliminary test exogenous to the educational institutions involved, allowed us to recognize a

Cronbach's Alpha index of 0.93 for the composite of polytomous indices, and 0.96 in the Kuder-Richardson index for the composite of dichotomous indices. It was more appropriate to measure consistencies in parallel without avoiding agglutinating totality tests in the calculation of these indices knowing that the instrument values independent factors according to the scores obtained (demand levels).

2.2. Procedure

Three groups were classified to test the general hypothesis: (a) experimental (situation 1), (b) experimental (situation 2), (c) control. Regarding the compared pairs, the first group was made up of individuals with a low level of cognitive demand, the second, with students who demonstrated a moderate level of cognitive demand. Both groups of subjects were exposed to the effects of disruptive gamification activities. The disruptive effects were compared with a control group in which pedagogical activities based on classical constructionism were applied. This group presented varied levels of cognitive demand. For the selectivity of subjects according to their medical condition, the vaccination document for minors issued by the Ministry of Health of Peru and the school registration form were recorded. Disruptive gamification involved the use of 20 didactic and leisure-oriented video games. 50% were adventure, 30% logical questioning; and the rest compiled games for sports competition and numerical-linguistic literacy. In turn, it included the development of 120 learning activities, in which the use of video games was intertwined before, during and after each didactic activity in the areas of mathematics, science and language. This method was composed of three execution phases: (1) Motivational exposure to the video game, (2) distracting exposure in the development of problems in the area, (3) exit motivational exposure. All the activities were carried out in groups, for which reason the motivational exposition included the work of duets and triads in the participation of the students (phase 1: motivational exposition to the video game). In this sense, the video game was considered a common distractor in the first 20 activities attached to the school curriculum. However, in the remaining 50 activities competitions were generated between groups of students; and, the remaining 50 activities were mixed. The same pattern occurred with phases 2 and 3 for each session. It was considered interspersing the disruptions in the two experimental groups, in order to intersperse effects and weigh them to avoid factors of boredom, apathy or reluctance in the face of repetition in the use of video games.

In the second phase of development (distracting exposure in the development of problems in the area), the scheme allowed practicing with the same modality with the difference that the cuts or disruptions were executed at the moment in which the students faced more complex problems. This was done according to the levels that they demonstrated in the pretest evaluation. In this sense, it was possible to reduce the cognitive overload in moments of tension due to the lack of resolution in the individual. On the other hand, the exit presentation (third phase) served to try to dissipate the tension before the task as an evaluation, for which an evaluation accompanied by the use of video games was used. In some cases, it was used as a way of clipping the evaluation itself. The problems used were balanced according to those used in the measurement test, this was done to standardize the levels of difficulty in relation to performance, without moving them away from the structural modality of the evaluation or the didactic models applied by the teachers of their classrooms. This would help to formulate more malleable emotional and attitudinal adaptations regarding the use of video games. The post-test evaluation was carried out two weeks after completing the application of the last activity After finishing the experiment, the application of this program for 30 days to the subjects of the control group was managed, and thus achieve equity and meet the criteria of justice on the performance of schoolchildren not addressed by the disruptive methodology.

As for the homologation of groups of students with determined levels of cognitive demand, this refers to the equalization of the performance that the students demonstrated in their schools after spending time in virtual education, which was deplorable in Peru due to external factors such as the school's economic level, social level, lack of technological and network resources to achieve effective classes. In this sense, we worked with students who showed low and moderate performance after having participated in virtual education since the pandemic, which was combined with the effects that Covid-19 had on many of them during the first and second waves of infection in the city of Lima. For this reason, we sought to grade their performance in order to compare it to the performance of others in Regular Basic Education, which was based on the performance scale on which these subjects performed in mathematics in the primary school grades they were in. The preliminary assessment model allowed to corroborate what was actually happening, among the assessment categories: A (achievement), B (fair), C (low), those students were chosen who showed to perform at levels B or C, who also demonstrated the clinical condition described above. For this reason, students at these levels were considered to be performing at a very low level of cognitive demand, so the preliminary assessment with pilot instruments helped to corroborate the cognitive gap they demonstrated in their schools. This criterion allowed them to be preliminarily selected for inclusion in the experiment.

2.3. Results and discussion.

The ratings of the control group presented representative accumulations that signified differences in certain levels of demand. Figure 1 shows the differences obtained in the pretest evaluations, these being significant for the mentioned group, which was corroborated in the statistical analysis ($t_{(83)} = -4{,}560$; $p < 0.05$). There were no differences worthy of inference between the control group and the second experimental group ($t_{(84)} = 0.230$; $p > 0.05$). The difference shown in figure 1 was also corroborated by Mann Whitney tests, obtaining similar results in the first contrast (U = 393.0; sig. = 0.00); as well as in the second (U = 867.0; sig. = 0.621). For this reason, the lack of balance between the first experimental group and the control group can be argued, but features of cognitive balance between the second experimental group and the control group are noted. Regarding the contrast results of the first pair (group with low demand versus control group) (figure 1), differences were found approximately five average points ($M_{(diff.)} = 4.86$; SD = 7.8), favorable to the first group. of experimentation ($t_{(83)} = -4{,}560$; $p < 0.05$). This has shown that subjects with a low level of cognitive demand in mathematics were able to overcome tasks with a moderate level or a high level of demand, compared to the group of subjects with different levels of performance.

For this reason, it is accepted that disruptive gamification has positive effects in improving abilities to tackle moderate or high-level tasks from cognition with students who initially showed a low level of response to cognitive demand in mathematics. This seems to present evidence that justifies the reduction of distractions and the lack of attention to problems that are increasingly complex thanks to the competition postulated by the playful disruption of gamification applied in the first [7, 10, 14]. Here it should be considered that as they are students with lower performance power, the health problems previously noted in the sample were combined. This can open new evidence on the level of development of students with lower abilities to face increasingly complex tasks [21]. Regarding the cognitive factor, it is well known that working memory and information acquisition abilities are adaptive in subjects who already know a common practice with moderate or high cognitive demand as already observed in other studies that reveal better representativeness of numerical quantities when reasoning is performed with great ease [22, 23, 24], but there is a greater demand on the use of working memory in complex mathematics in information users who show less ability to encode implicit information than those with higher abilities [24, 25]. It is deduced that this has occurred, especially in the tasks that required changes in the work with the experimental group of the sample. For these reasons it has been found that the possibility of additional factors besides cognitive factors such as stress symptoms drawn from health status, emotional well-being as well as self-regulation in mathematics can be obstructed by the complexity of the task, even more so if these influences are biologically or psychologically dependent. In this sense, it should be considered that health problems may have affected performance, although it was not a central part of this study, this characteristic assured the possibility that disruptive gamification has more accurate effects than the usual gamification found in the literature on gamified education. It should be noted that the difference obtained in the post-test contrast of the first pair presented significances very close to 5% in the calculation of the confidence rate; however, the Mann-Whitney test allowed us to corroborate the differences from the non-parametric perspective (U = 508.0; sig. = 0.00).

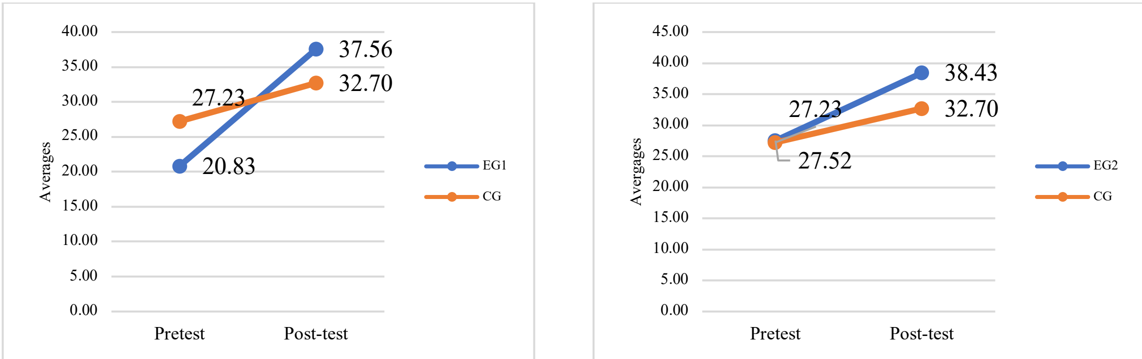

Figure 1: Averages in the pretest and posttest comparisons according to the level of demand.

Figure 1 also shows values derived from the posttest comparison of the second pair. Here an approximate difference of ten average points has been obtained, which has been favorable to the second experimental group ($M_{(diff.)} = 5.73$; SD = 9.09). This reveals that students with abilities to solve tasks with a moderate level of cognitive demand also do so at a high level ($t_{(84)} = 3.278$; $p < 0.05$). Therefore, these individuals demonstrated a better increase in their ability to address certain levels of cognitive demand in mathematics, as has already been obtained in studies that refer to the relay of more powerful levels to solve more complex problems in students who demonstrate the development of working memory with less cognitive load, if they are motivated with gamification rewards [23, 25]. In this part of the study, it was possible to overcome the use made of the motivational effects of the game applied in didactics or traditional teaching [8, 28]. Up to now we have overcome the didactic capacity of typifying a direct and transversal gamification, assuming a more longitudinal and cutting gamification, where the disruption or the cuts of the recharge of the working memory based on rest spaces work better. Even more so when the study subjects developed more complex problems. This differs from other studies [9, 10, 11, 29], since the moments of distracting exposure (second moment) and the moment of evaluative exposure (third moment) have been developed.

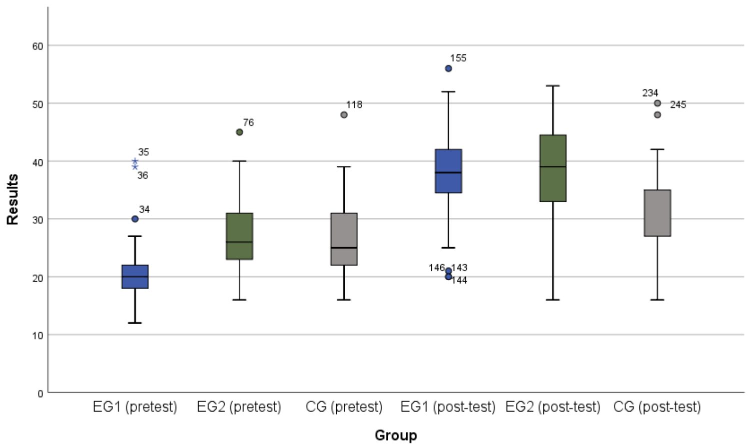

Figure 2: Intergroup box plot of the pretest and post-test evaluations.

Regarding the advances with respect to the averages reached by each pair, in Figure 2 the highest quartiles can be found in the three groups in the results of the post-test evaluation. However, the median is denoted with a higher value in the second group (EG 2) compared to the remaining groups. In an analysis related to outstanding values, we obtained three higher values in terms of cognitive demand in the first group, which obtained scores of 50, 52 and 56. In the second group, six cases were referred (51, 50, 53, 50, 52, 51); and in the control group, one case was detailed (50). The decisive score limit was 50 or more points, in order to consider that students who exceeded their own level of cognitive demand become more capable of overcoming more complex tasks from immersion in gamified didactics with disruption. It is also evident that they have the cognitive characteristics to reach high levels of mathematical competence. Some studies have reported without detail that gamification is more responsive and more interactive with the influence of gamified work [16, 17, 18, 19], and in those in which rewards are integrated, and among which challenges develop spontaneously [27, 28]. This assumes the credibility of an important model, which is didactically sober with strategies without dazzling the minds of students with attractive games for leisure, but only if the needs demand it can only be disruptive distracters that contribute to educational processes and not just gamify them without pedagogical meaning and intention [13, 18, 19, 30]. Using them without guidance would lead to the development of other more complex affectations such as uncontrolled desire and attention-reducing compulsive gambling.

However, in our research we report cases that exceeded the cognitive expectations beyond the hypotheses considering the initial unevenness that was demonstrated in the first pair compared to the pretest assessment, without trying to train them with the intrinsic leisure of the games. It is important to accept that gamification can be fun, but many times it should be avoided so as not to overload the student in the complexity training process. It is evident that the use of videogames has allowed to capture greater motivation towards distractions, but the collaboration in these games has also allowed the use of cooperative strategies to develop problems of these videogames and common mathematics in class. It was obvious that the students in the second experimental group would find themselves with more possibilities to respond more easily to more demanding mathematical difficulties, but the progress of students with low performance in cognitive demand is much more notable. This has shown that disruptive gamification can contribute to the development of mathematical thinking, and enables the conditions for motivation in subjects with fewer possibilities to perform at the same or higher level than their peers located in the control group.

3. Conclusions.

According to what has been stated, it can be asserted that disruptive gamification influences the characteristics of compared groups. The students who started the experiment with a low level of cognitive demand were able to reach moderate type levels and, in some cases, high type levels ($M_{(diff.)} = 4.86$; $SD = 7.8$; $t_{(83)} = -4{,}560$; $p < 0.05$). On the other hand, individuals with moderate levels evidenced before receiving treatment overcame the complexity barrier through participation and evaluation with disruptive gamifiers. In this case, the health problems associated with the sample characteristics did not impede the development of the experiment, however, in the first pair compared, the difficulty they present in reaching higher levels of development is noted. This differs from the second pair of groups, in which the comparison demonstrated improvement in the performance of more complex tasks in subjects with moderate levels of mathematical cognitive demand ($M_{(diff.)} = 5.73$; $SD = 9.09$; $t_{(84)} = 3.278$; $p < 0.05$). Regarding the methodology, it can be concluded that it is sensitive to reduce the possible expressions of frustration and rejection that appeared in some cases of students who failed to develop increasingly complex mathematics. The implication of interactive activities in didactics with the use of video games, as well as motivation, the construction of learning or in its evaluation, promoted the clearance of such characteristics without involving ambiguous or biased distractors.

It is important to develop research that explores the mathematical cognitive demand with the use of disruptive gamifiers, comparing groups of students according to each level. This could deepen the cognitive arrival that students have according to the instrumental characteristics used. It should be remembered that the initial contribution of the study compares the effect of gamification in two pairs of groups based on the cognitive characteristics of each group, without exploring the levels of demand, more only knowing how far they could go with their mathematical skills.

References

[1] G.C. Calsa, P. Furtuoso, Estudo sobre a prática de alfabetização matemática de professoras da educação infantil, Revista Educação e Linguagens, Campo Mourão 4(6) (2015) 124-141. http://www.fecilcam.br/revista/index.php/educacaoelinguagens/article/view/804

[2] H.P. Gusmão, Análise das eleições e decisões dos estudantes quando enfrentam situações-problema de matemática: uma contribuição desde a didática fundamental da matemática, Santiago de Compostela, España: Ph.D. Universidad de Santiago de Compostela, 2016. https://minerva.usc.es/xmlui/handle/10347/13972

[3] A. Tafarelo, A. Bonanno, A construção do conceito de número e suas implicações na aprendizagem das operações matemáticas, in: Proceedings of the XII Encontro Nacional de Educação Matemática, Educação Matemática na Contemporaneidade: desafios e posibilidades, Brasil, 2016, pp. 1 – 12. http://www.sbem.com.br/enem2016/anais/pdf/5122_3136_ID.pdf

[4] L. Canet-Juric, I. Introzzi, M.L. Andrés, F. Stelzer, The contribution of Executive Functions to Self-regulation, Cuadernos de Neuropsicología, Panamerican Journal of Neuropsychology, 10(2) (2016) 106-128. http://www.cnps.cl/index.php/cnps/article/view/238/253

[5] L. Radford, Introducción. Semiótica y Educación Matemática, Revista Latinoamericana de Investigación en Matemática Educativa, Especial – RELIME, (2006) 7 – 22. https://www.redalyc.org/articulo.oa?id=33509902

[6] A. Sáenz-Ludlow, Interpretation games in the classroom: evolutionary construction of mathematical meanings, in: R. Duval, & A. Sáenz-Ludlow (Eds)., Understanding and learning in mathematics: selected semiotic perspectives, Universidad Distrital Francisco José de Caldas, Colombia, 2016, pp. 157 – 192.

[7] M.K. Stein, M.S. Smith, M. Henningsen, E. Silver, Implementing standards-based mathematics instruction: A Casebook for Professional Development (2nd ed.), National Academy Press, United States of America, 2009.

[8] J. Suh, P. Seshaiyer, Examining teachers' understanding of the mathematical learning progression through vertical articulation during lesson study, Journal of Mathematics Teacher Education 18(3) (2015) 207-229. doi: 10.1007/s10857-014-9282-7

[9] S. Caviedes-Barreda, G. de Gamboa-Rojas, E. Badillo-Jiménez, Mathematical connections established by pre-service teachers when solving measurement and comparison tasks of area, Praxis, 15(1) 69-87, 2019, doi: 10.21676/23897856.2984.

[10] P. Dalsgaard, K. Halshov, C. Nylandsted, Chapter 7 - A study of a digital sticky note design environment, in: T. Bo, K. Christensen K. Halshov, C. Kolkmose, Eds., Sticky Creativity, Elsevier Inc., 2019, pp. 155-174.

[11] L. Mwadzaangati, Comparison of geometric proof development tasks as set up in the textbook and as implemented by teachers in the classroom, Pythagoras 40(1) (2019)1-14. doi: 10.4102/pythagoras.v40i1.458

[12] A. Andriani, I. Dewi, and P.N. Sagala, Development of blended learning media using the mentimeter application to improve mathematics creative thinking skills, Journal of Physics: Conference Series 1188 (2019) 1-6, doi: 10.1088/1742-6596/1188/1/012112

[13] M. Kalogiannakis, S. Papadakis, Gamification in Science Education. A Systematic Review of the Literature. Educ. Sci. 11(1), (2021) 1-36. doi: 10.3390/educsci11010022

[14] N. Martínez, J. Barceló-Doménech, M. Heras, R. Evangelio, M.R. Guilabert, C. Lamarca, L. Molina, V. Múrtula, B. Serrano, The application "Mentimeter" for the creation of word clouds and the dynamization of the explanation of legal-civil concepts. Redes de Investigación e Innovación en Docencia Universitaria, (2020) 897-905. http://hdl.handle.net/10045/110128

[15] T-H. Huang, Y-C. Liu, C.-Y. Shiu, Construction of an online learning system for decimal numbers through the use of cognitive conflict strategy, Computers & Education, 50(1) 2008, 61-76. doi: 10.1016/j.compedu.2006.03.007
[16] K.M. Kapp, The Gamification of Learning and Instruction: Game-Based Methods and Strategies for Training and Education. Int. J. Gaming Comput. Simul. 4, (2012) 336p.
[17] C.A. Scolari, R. Winocur, S. Pereira, C. Barreneche, Transmedia literacy. An introduction, Comunicación y Sociedad, 33, (2018) 7-13. http://www.comunicacionysociedad.cucsh.udg.mx/index.php/comsoc/article/view/7227
[18] A.M. Toda, W. Oliveira, A.C. Klock, P.T. Palomino, M. Pimenta, I. Gasparini, L. Shi, I. Bittencourt, S. Isotani, A.I. Cristea, A Taxonomy of Game Elements for Gamification in Educational Contexts: Proposal and Evaluation, in: Proceedings of the 19th International Conference on Advanced Learning Technologies (ICALT), IEEE., (2019) 15-18. doi: 10.1109/ICALT.2019.00028.
[19] A.M. Toda, P.T. Palomino, W. Oliveira, L. Rodrigues, A.C.T. Klock, I. Gasparini, A.I. Cristea, S. Isotani, How to Gamify Learning Systems? An Experience Report Using the Design Sprint Method and a Taxonomy for Gamification Elements in Education, Journal of Educational Technology & Society 22(3) (2019) 47–60. https://www.jstor.org/stable/26896709
[20] Y. Ni, D. Zhou, X. Li, Q. Li, Relations of instructional tasks to teacher-student discourse in mathematics classrooms of chinese primary schools, Cognition and Instruction 32(1), (2014) 2-43. doi: 10.1080/07370008.2013.857319
[21] Y. Ni, D-H.R. Zhou, J. Cai, X. Li, Q. Li, I.X. Sun, Improving cognitive and affective learning outcomes of students through mathematics instructional tasks of high cognitive demand, Journal of Educational Research 111(6) (2018) 704-719. doi: 10.1080/00220671.2017.1402748
[22] M.F. Maier, M.P. McCormick, S. Xia, J. Hsueh, C. Weiland, A. Morales, M. Boni, M. Tonachel, J. Sachs, C. Snow, Content-rich instruction and cognitive demand in prek: using systematic observations to predict child gains 60 (2022) 96-109. doi: 10.1016/j.ecresq.2021.12.010
[23] J.M. Caemmerer, M.R. Reynolds, T.Z. Keith, Beyond individual tests: Youth's cognitive abilities on their math and writing skills 102 (2023) 102271. doi: 10.1016/j.lindif.2023.102271
[24] S-C. Kong, Y-Q. Wang, Monitoring cognitive development through the assessment of computational thinking practices: A longitudinal intervention on primary school students, Computers in Human Behavior 145 (2023) 107749. doi: 10.1016/j.chb.2023.107749
[25] M. Srivani, A. Murugappan, Design of a Cognitive Knowledge Representation Model to Assess the Reasoning Levels of Primary School Children, Expert Systems with Applications 231 (2023), 120604. doi: 10.1016/j.eswa.2023.120604
[26] D. Alt, Assessing the benefits of gamification in mathematics for student gameful experience and gaming motivation, Computers & Education 200 (2023) 104806. doi: 10.1016/j.compedu.2023.104806
[27] O. Baydas, M. Cicek, The examination of the gamification process in undergraduate education: a scale development study, Technology, Pedagogy and Education 8(3) (2019) 269-285, doi: 10.1080/1475939X.2019.1580609
[28] Y-H. Wang, Design-based research on integrating learning technology tools into higher education classes to achieve active learning, Computers & Education 156, (2020) 103935. doi: 10.1016/j.compedu.2020.103935
[29] E. Zimmerling, C.E. Höllig, P.G. Sandner, I.M. Welpe, Exploring the Influence of Common Game Elements on Ideation Output and Motivation, J. Bus. Res. 94, (2019) 302–312. doi: 10.1016/j.jbusres.2018.02.030
[30] P. Loganathan, C. Talib, N. Thoe, F. Aliyu, R. Zawadski, Implementing Technology Infused Gamification in Science Classroom: A Systematic Review and Suggestions for Future Research, Learn. Sci. Math., 14 (2019) 60–73. http://recsam.edu.my/sub_lsmjournal/images/docs/2019/2019_5_PL_6073_Final.pdf
[31] M.D. Baldeón-de la Cruz, J.A. Holguin-Alvarez, G.M. Villa-Córdova, Provocation by Challenges: Optimizing Experience of Addressing Mathematical Tasks With High Cognitive Demand, Revista Electrónica Educare, 24(3) (2020) 1-20. doi: 10.15359/ree.24-3.9