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Gamification on Working Memory: The Use of Puzzles in Advancing Education Outcomes in Qatari Public Schools

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Abstract

This paper investigates the effect of gamification tools on the learning outcomes of an educational program that uses football to convey keywords representing the life skills students are expected to develop throughout the program. During each session, three keywords were reinforced. To enhance the retrieval abilities of students (n=732) from Grades 3 to 6, a behavioural intervention was rolled out, consisting of six sets of puzzles that each formed a keyword. Students in the treatment group were asked to assemble the puzzles corresponding to the three keywords of the session, while control students followed the standard planned reflection. Students were then quizzed on their ability to recognize the

keywords from among a list of words. The intervention resulted in a 14.2% increase in the number of correct words identified, significant at the 5% level, with the keyword ‘communication’ showing a retention rate 25.3 percentage points higher in the treatment group compared to control. Such findings support the implementation of gamification tools in educational settings, as they can be helpful in developing students’ working memory, which is instrumental in bridging abstract concepts and practical, applicable life skills.

Keywords: Gamification, Behavioural science, Working memory, Retrieval practice, Learning outcomes

1. Introduction

Generation Amazing is one of the delivery initiatives of the FIFA World Cup 2022 in Qatar. It was established with the objective of developing programs that use football to empower youth and tackle priority social issues in Qatar, the region, and the world. Their Football4Development methodology uses football as the delivery framework through which key life skills are taught to children and young adults. In 2019, Generation Amazing, delivered a Football4Development program in Qatari government schools for girls and boys. This program used football and football-related activities to teach students from Grade 3 to 6 abstract concepts such as teamwork, communication, problem-solving and respect. To enhance the learning experience, B4Development designed a behavioural intervention aimed at improving students' ability to retain and retrieve some of the keywords used during the Football4Development sessions. The intervention consisted of an RCT that provided schools assigned to the treatment group with six large colourful puzzles, each spelling one of six selected keywords, while the control group schools received the usual program designed by Generation Amazing. Coaches would ask students to assemble these puzzles as part of the Football4Development sessions, rotating them between groups of students to ensure exposure to all puzzles. Before the fourth session, students in both control and treatment schools were quizzed on their ability to remember the words they had been taught.

1.1 Retrieval Practice

Retrieval practice consists of promoting the retrieval of studied information by "taking the information out of students heads" (Agarwal, D'Antonio, Roediger, McDermott, & McDaniel, 2018) and it has been one of the most effective learning strategies as it strengthens memory features and promotes long-lasting learning (Ekuni & Pompeia, 2020). A review by Mendonça and Ekuni (2022) of 41 experimental designs that evaluated the effect of retrieval practice of children between the ages of 18 months to 12 years showed that interventions mostly led to significant improvements to long term learning and new learning, especially when feedback was provided. All of the evaluated designs followed a five-phase methodology, synthesized by Mendonça and Ekuni which serves as a useful framework to guide similar interventions (most of the appraised experiments were conducted in classroom settings):

I. Students are introduced to information to be learned

II. Lag- period between introduction and retrieval practice

III. Students are introduced to retrieval practice once or repeatedly

IV. Retention interval between retrieval and final test

V. Retention assessed by a test

Interventions based on retrieval practice have shown promising results, as it is reported to facilitate learning (McDermott, 2021), lead to better memory performance and long-lasting learning (Yang, Luo, Vadillo, & Shanks, 2021). It is also reported that increasing the number of retrieval practices leads to better results (Leonard & Deevy, 2020). Specifically related to recognition of key words, retrieval practice has shown to increase the recall of keywords

significantly (Moreira, Pinto, Justi, & Jaeger, 2019, 2019).

1.2 Working Memory and Learning

The concept of working memory refers to the small amount of information (often abstract) that is stored in readily accessible form and facilitates comprehension, reasoning, immediate planning, problem solving, and the overall execution of cognitive tasks (Cowan, 2014). Working memory is often related to intelligence, information-processing and learning. Concepts start in working memory when children are able to recall the characteristics of a concept, and once the concept is learned it is transferred to long-term memory (Nelson, 1974). This in turn establishes a systematic process where working memory allows individuals to process and retain information which is then stored in long-term memory and can be retrievable in the future (Baddeley, Papagno, & Vallar, 1988). However, complex concepts may tax working memory, often flawing the long-term memory building process and requiring reparational efforts to amend discrepancies, which emphasizes the importance of cementing a correct understanding of abstract concepts during formative years (Cowan, 2014). Cowan (2021) tested the performance of children of different ages on two non-verbal working memory tasks, noticing that picture memory tasks had a positive effect on receptive vocabulary, especially among younger children. Similarly, puzzles have been used to evaluate children's visual active working memory at different points in time, demonstrating that stimulating spatial working memory increases early numerical performance (Fanari, Meloni & Massidda, 2019). There is also evidence pointing at improvements to working memory performance among children through gamification strategies, such as using a picture-rhyming game (Cowan, Nugent, Elliott, Ponomarev, & Sault, 1999) mnemonics (Ornstein & Naus, 1978), and cognitive behavioral play therapy (CBPT) used on children with specific learning disorders (Azizi, Drikvand, & Sepahvandi, 2018).

1.3 Gamification

Gamification refers to the addition of game elements to non-game activities (Anonymous, n.d.), invoking the same experiences that games generally do (Huotari & Hamari, 2012). It has successfully been integrated commercially into platforms to create targeted relationships between products and users, in order to increase its popularity (Dom ńguezs et al., 2013). However, research also proposes that gamification has a major role in education, for instance, to increase student engagement and achieve learning standards (Lee & Hammer, 2011). Additionally, there is evidence suggesting that gamification can address issues such as lack of student motivation, especially in virtual learning environments (Liaw, 2008). A paper by Hamari et al. (2014) that gathered 24 empirical studies on gamification found that all results pertaining to these studies in educational contexts, were in favour of gamification, with positive learning outcomes. These outcomes were measured in terms of increased motivation, engagement in learning and enjoyment (Hamari, Koivisto, & Sarsa, 2014). Reported increases in competition and reduced attention can be mitigated by removing point or reward affordances. Schneider emphasizes the importance of memory strategies such as rehearsal and semantic organization to improve the memory performance of children between the ages of 5 and 10 (Schneider, 2010). These strategies can take place at the learning (encoding) stage

or when information is accessed in the long-term memory (retrieval) stage, although recalling the interrelatedness of these two processes identified by Baddeley et al. implementing gamified memory strategies during the learning stage may be more beneficial (Baddeley, Papagno, & Vallar, 1988). More recent studies have demonstrated the effectiveness of gamification on learning outcomes and engagement; a study by Nand, Baghaei, Casey, Barmada, Mehdipour, and Lang (2019) showed that gamified educational computer content increased children's numeracy skills and overall engagement. Similarly, Ricoy & Sánchez-Martínez (2022) used gamification to increase primary school children's environmental awareness, resulting in the acquisition of new resource conservation strategies and better recycling practices that went beyond the classroom.

2. Methods

2.1 Intervention

A behavioural intervention was designed in order to increase students' ability to retrieve six of the 18 keywords used throughout 12 scheduled Football4Development sessions. Large 6-piece puzzles were made for each of the six selected words (respect, teamwork, communication, listening, problem solving and body language) in Arabic, as shown in Figure 1. The mean number of letters in each keyword in Arabic was 8.83, with communication being the shortest and teamwork being the longest.

Figure 1. Sample of key-word puzzles

During the weekly sessions, students from Grades 3 to 6 would perform football drills that focused on life-skills related to one of the three words reviewed in each session. For instance, if one of the keywords of the session was teamwork, the drills would seek to practically reinforce collaboration between team members, making teamwork instrumental to succeed on the task. The drills had the same format for all students, as the format was adaptable to a higher level of motor skill, expected from students from higher grades. Students in the treatment group would assemble three puzzles related to the three keywords every session was dedicated to. In session 1, the keywords were: teamwork, communication and listening. In session 2, the keywords were respect, communication and listening and in session 3, the keywords were: problem-solving, teamwork and body language. Before the beginning of the fourth session, students were quizzed by asking them to identify the keywords from a list of

12 keywords that included six unrelated terms. The experiment followed the five-phase framework for retrieval practice interventions:

Figure 2. Retrieval practice framework

Every one of the 12 words had a score, so if students selected a keyword, the score for that word would be 1, and the score would be 0 if students wrongly selected a word that was not part of the keywords. Similarly, if students failed to select a keyword, the keyword would be given a score of 0, but if an unrelated word was not selected, it would be given a score of 1. While the program was intended to last for 12 weeks and initially it was planned to have another quiz at the end of the program, the COVID-19 pandemic interrupted the delivery at week 4, which only allowed for one quiz to be administered.

2.2 Sample and Randomization

The total sample included all students from Qatari government schools that took part in the Football4Development program (n=853). From the 18 schools that participated in the program, 11 were boy-only schools and 7 were girl-only schools. The program was delivered by 16 coaches trained by Generation Amazing, and each coach was assigned to deliver sessions to all the selected classes in one school. Two coaches were assigned to two schools instead of one. Coaches were randomly assigned to a treatment group —where they would be given a set of puzzles to integrate as part of the sessions—or a control group, where they would conduct the sessions as planned, with no additional material. Randomization was done at the level of the coaches to mitigate spill-over effects and simplify the distribution of puzzle sets. Nine coaches were assigned to control groups while six were assigned to treatment groups. Observations from one of the coaches were excluded after noticing that she was assigned to a treatment and a control school, risking spill-overs.

3. Results

3.1 Multivariate Analysis on the Number of Right Answers

A multivariate analysis was used to explain the variation in the number of right answers, R_{ij} of the j^{th} student assigned to the i^{th} coach. The equation was adjusted controlling for the gender and the grade of the student, further controlling for the fixed effect of class size:

$$R_{ij} = \alpha + \beta_1 TC_i + \beta_2 Total_{ij} + \beta_3 Gender_{ij} + \beta_4 Grade_{ij} + \varepsilon$$

$$R_{ij} = \alpha + \beta_1 TC_i + \beta_2 Total_{ij} + \beta_3 Gender_i + \beta_4 Grade_{ij} + \beta_5 Class\ size_{ij} + \varepsilon$$

The table below shows the results of the intervention on the number of right answers using

four different models. The magnitude of the effect ranges between 12 and 15%, significant in all of the models. Model (3) shows a 14.2% increase in the number of selected right answers, significant at the 5% level.

Table 1. Results using four different models

Dependent variable: Log (Number of Right Answers)				
	(1)	(2)	(3)	(4)
Treat	**0.86***	**0.80***	**0.59****	**0.55***
	(0.066)	**(0.065)**	**(0.06)**	**(0.059)**
	[0.055]	**[0.057]**	**[0.02]**	**[0.053]**
Log (Total number of circled answers)	0.75***	0.75***	0.77***	0.78***
	(0.061)	(0.061)	(0.054)	(0.05)
Number of students per class		0.006	0.0014	-0.0016
		(0.007)	(0.007)	(0.006)
Gender of School			0.198***	0.21***
			(0.063)	(0.06)
Grade Dummies	No	No	No	Yes
Observations	732	732	732	732
R^2	0.44	0.45	0.5	0.52

*** p<0.01, ** p<0.05, * p<0.1
Robust standard errors clustered on the section level are shown in parentheses

A three-level GLM model was used to estimate the effect of the treatment on the number of right answers relative to wrong answers. Students circled 1.26 more right answers than wrong answers as a result of the puzzle intervention, significant to the 5% level.

Table 2. Three-Level GLM Model

```
Mixed-effects GLM                               Number of obs     =        732
Family:                  Gaussian
Link:                    identity

------------------------------------------------------------------------------
                |  No. of       Observations per Group
 Group Variable |  Groups    Minimum    Average    Maximum
----------------+-------------------------------------------------------------
          coach |      15         18       48.8        117
        section |      30         15       24.4         33
------------------------------------------------------------------------------

Integration method: mvaghermite                 Integration pts.  =          7

                                                Wald chi2(6)      =      27.64
Log likelihood = -1461.4316                     Prob > chi2       =     0.0001
------------------------------------------------------------------------------
        diff |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          TC |    1.125751   .5645357     1.99   0.046     .0192814    2.232221
       Total |   -.0660196   .0370974    -1.78   0.075    -.1387291    .0066899
_IGender_Sc_2 |    1.796557   .5201925     3.45   0.001     .7769988    2.816116
    _IGrade_2 |    .0073713   .9006275     0.01   0.993    -1.757826    1.772569
    _IGrade_3 |   -.5635066   .9943068    -0.57   0.571    -2.512312    1.385299
    _IGrade_4 |   -1.148457   .9779459    -1.17   0.240    -3.065196    .7682816
        _cons |     2.48587   1.009706     2.46   0.014     .5068821    4.464858
------------------------------------------------------------------------------
coach
   var(_cons) |    .7926031   .3855382                      .305502    2.056352
------------------------------------------------------------------------------
coach>section
   var(_cons) |    .3353527   .1615713                     .1304358    .8621973
------------------------------------------------------------------------------
  var(e.diff) |    2.919583   .1558145                     2.629621    3.241517
------------------------------------------------------------------------------
LR test vs. linear model: chi2(2) = 185.07                Prob > chi2 = 0.0000
```

3.2 Multivariate Analysis on Word Retention Rate

The following equation is estimated to explain the variation in the retention of the six correct words from among the list of 12 words:

$$W_{ij} = \alpha + \beta_1 TC_i + \beta_2 Total_{ij} + \beta_3 Gender_{ij} + \beta_4 Grade_{ij} + \varepsilon$$

The response rates W_{ij}, of the j^{th} student, assigned to the i^{th} coach are regressed on the TC variable along with a set of control variables including gender, class size and grade of the student. In another specification, we adjust for the class size and month of exam fixed effects.

For the word "problem solving", the statistical analysis controlling for gender, class size and grade showed an increase of 17.8 percentage points, significant at the 5% level. For the word "communication", the statistical analysis showed an increase of 25.3 percentage points, significant at the 1% level, as shown in the panel below. The intervention did not seem to have a significant impact on the retention rate for the rest of the keywords.

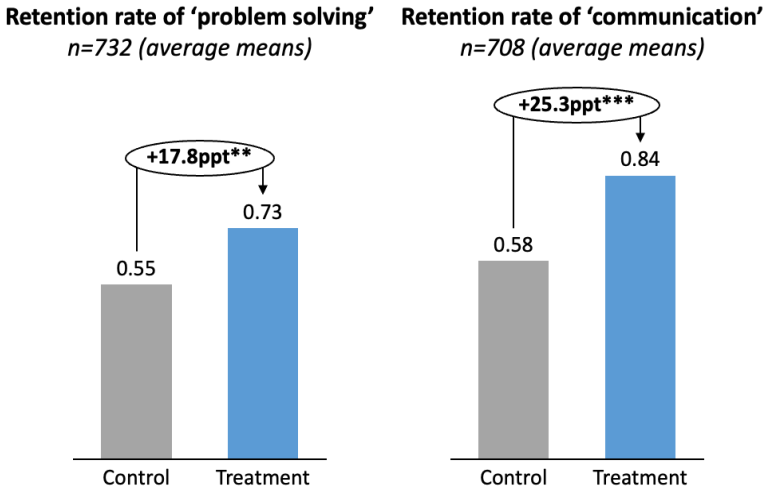

Figure 3. Retention rates of keywords "problem solving" and "communication" in control versus treatment

3.3 Additional Findings

The significant increase in the retention rates of "problem solving" and "communication", was associated with a significant decrease in wrongly selecting the word "excellence" or the word "learning", both of which were not part of the six keywords, with the first being significant at the 1% level and the second at the 5% level. Therefore, not only did the puzzle intervention led to a better retention of the two mentioned keywords, but also to a better discrimination of two of the wrong answers, compared to the control group.

Similarly, the intervention seemed to have a higher impact on lower grades; compared to Grades 5 and 6, Grade 4 students show a larger increase in the number of correct answers.

However, the differential effect is only significant at the 5% level when comparing Grade 4 to Grade 6 students. Separately, while girls seemed to retain words better than boys, the results were not significant. Finally, while the puzzles were designed in blue, green and red (two of each), there was no difference in correct responses by colour.

3.4 Discussion

The results reveal that gamified strategies such as word puzzles can help older, literate children to retrieve concepts they have learned before. Compared to students who received the simple reflection exercise as part of the session, those in the treatment group seem to recall key concepts more successfully. While there is no quantitative evidence to claim that the puzzle intervention itself helped children encode the concepts on their long-term memory, it can be argued that improved performance in working memory is likely related to a more accurate understanding of concepts that can be used in the long-term. There is evidence in the literature, however, that supports the case for puzzle interventions as a useful way to evaluate learning outcomes beyond just memorization (Fanari, Meloni, & Massidda, 2019). In general the results indicate that retrieval practice works better than traditional study methods on word recognition skills in the short and middle term, as supported by other studies (Moreira, Pinto, Justi, & Jaeger, 2019).

Interestingly, the keywords “problem solving” and “communication” had the best rates of retention among treated students. Contrary to what was expected, students did not have better retention of single-word terms (“problem solving” in Arabic is made up of two words too). However, “communication” may have been recalled with more accuracy due to the fact that it was the only word reinforced during session one and session two. There is evidence that more iterations of retrieval lead to better results (Leonard & Deevy, 2020). While “problem solving” was presented until session three, it may have been recalled with more accuracy because of its direct relationship with the activity: children may have associated arranging the puzzle sets with problem solving.

Some of the limitations are inherent to inequalities within the education system in Qatar, where some students, especially in lower grades, may still be unable to read and write, either in English or Arabic. This was observed in some, albeit isolated cases, and when spotted, responses were dropped. However, it is also possible that students without full literacy may have copied answers from their peers, despite efforts to avoid communication between students during the quiz. Another structural limitation was due to the COVID-19 pandemic, which cut the program short and also made it impossible to quiz students later in the school year to test the sustainability of the intervention in long-term memory retention. Finally, it is important to note that the recognition of words via circling items in a list and not recalling by writing down the words that students remember may have influenced their memory retrieval, as it is easier to recognize than to recall. Future studies would benefit from testing students’ ability to recall words without a list, test them in the future to measure long-term impact, and most importantly, use different methods to go beyond retrieval and test for actual understanding and application of the learned concepts.

The results are a valuable first step in the right direction of the diversification of education

strategies. A fun exercise such as the puzzles can help educators cement students' memorization and understanding of important concepts, both tangible and abstract. Evidence from qualitative studies support the claim that gamification tools can go beyond knowledge acquisition and translate into practical life skills, which is one of the core objectives of the Football4Development program (Ricoy, Sánchez-Martínez, 2022). Moreover, this study adheres to the five-phase schema of experimental procedure followed by various interventions based on retrieval practice among children, contributing to an ongoing discourse that is mainly cantered in the US and English-speaking contexts (Mendonça & Ekuni, 2022). The intervention increased the number of right answers of those with lower scores, so puzzles can also be used as a tool in remedial education programs, as the effect was much larger among students with a higher wrong answer and lower right answer rates. Puzzles can also be non-verbal (using pictures or outlines) in order to explore different ways of stimulating working memory, especially among lower grades and settings with challenged literacy, based on evidence by Cowan, 2021.

When it comes to the outcomes of Generation Amazing Footbal4Development programs, puzzle interventions and other gamification techniques can be used to help students learn keywords and take them to football practice, effectively bridging the abstract and the concrete. The results of this intervention support the argument that behaviourally-informed tools that employ gamification have a better impact on learning outcomes than simple reflection exercises. More iterations of similar interventions can be used to scale up similar gamified content in the classroom and beyond, using insights from contextually similar benchmarks. For instance, using good graphics, giving feedback, and challenging students increases engagement (Nand, Baghaei, Casey, Barmada, Mehdipour & Lang, 2019), and non-verbal elements can be employed to make the content more accessible for younger students with limited literacy or special needs children. Overall, this intervention constitutes a low-cost alternative that teachers and coaches can use in educational settings to advance primary learning outcomes and promote life skills and positive habits more efficiently.

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Appendix

Appendix 1. CONSORT 2010 Flow Diagram