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Investigating the use of LEGO® Bricks in education and training: A systematic literature review

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Abstract

Despite the increasing attention paid to LEGO® as a learning tool rather than a child's toy, teaching practices and methodologies for using LEGO® vary according to educational contexts. The purpose of this paper was to investigate the various educational contexts of LEGO® usage in higher education and to identify trends in teaching practices. A systematic literature review was conducted on the use of LEGO® bricks in education and training using an exploratory sampling approach. A total of 298 articles were explored in internationally recognized journal databases using keyword search, and 26 articles were selected for a detailed review. We found a clear distinction in LEGO® usage between learning facilitation and thinking facilitation, as well as between individual application and group application. A simple typology with four quadrants is proposed based on our findings to help novice educators introduce LEGO® into their pedagogical designs.

1. Introduction

The use of LEGO® as a teaching and learning tool is not new (Giddings, 2017). When using LEGO® in learning, the aim is usually to engage learners through play and kinesthetic (hands-on) experiences to help deepen their learning (Lauwaert, 2008). This is grounded in constructionist learning theory, which suggests that people learn best by building or constructing things (Papert, 1999). In other words, adults learn by "thinking through our fingers" as opposed to the popular assumption that the brain thinks first and tells the hands to act (O'Brien, 2019; Papert, 1999; Papert & Harel, 1991; Peabody & Noyes, 2017). Papert (1999) explains that when adults build or construct objects, abstract ideas become more concrete and visual, and therefore more understandable. Applying this to the use of LEGO® in teaching and learning, the nature of LEGO® pieces provides learners with opportunities to construct and feel the models/sculptures, thus activating a richer kind of learning (Peabody & Noyes, 2017).

Other approaches associated with constructionist learning include the use of programming (Csizmadia et al., 2019) and creative experimentation (Psenka et al., 2017) in teaching and learning. In contrast to other approaches, the unique characteristic of LEGO® as a learning tool is the "play and fun experience," which is associated with toy model building using LEGO® pieces (James, 2013; Peabody & Noyes, 2017). When used in teaching and learning, it opens up the curiosity of the learners, as some participants may rekindle their childhood playtime hobby, while other first-timers may get their inaugural experience of playing with LEGO®. As the lesson proceeds, "playing and building" with the LEGO® bricks injects a fun atmosphere into the learning setting, which draws learners into the lesson.

Research on the use of LEGO® in education and training has been increasing in recent years (James, 2013; Peabody & Noyes, 2017). This increase appears across the spectrum of disciplines, including science, engineering, arts, and business studies, and encompasses a very wide range of student experiences from higher education to professional training (Kristiansan & Rasmussen, 2014). LEGO® is also applied in many different methodologies, including LEGO® SERIOUS PLAY® and LEGO® Mindstorms (Ranscombe et al., 2019). Despite the long history of the study of LEGO® in education, systematic literature reviews summarizing the effects of LEGO® in learning and training are limited. As such, the effectiveness of LEGO® as a learning tool is still unclear because this method is used across a large range of disciplines, with the majority of studies being descriptive in nature, based on reports of facilitators' observations (McCusker, 2019; Peabody, 2015; Pike 2002). While there are indications that LEGO® could be a useful tool for improving students' learning, it is unclear whether this assertion is supported by empirical evidence. The central question that this study attempted to answer is how LEGO® as a learning tool is applied across all disciplines and methodologies and whether the results are based on empirical evidence. Therefore, the purpose of this paper was to investigate various educational contexts of LEGO® usage in higher education and to identify trends in teaching practices. We also aimed to define future research perspectives regarding the use of LEGO® as a learning tool based on the literature reviewed. Conducting a literature review allowed us to better understand how LEGO® as a teaching and learning tool has evolved over the years, thereby identifying the current research trends and exploring future research opportunities. Regarding the educational application of LEGO® bricks, Xia and Zhong (2018) reviewed 22 journal papers on robotics education in K-12 students. They found that there was a dominant position of LEGO® as a learning tool at the level of elementary education, but the situation has not yet been examined at the level of higher education. Souza et al. (2018) conducted a systematic review of LEGO® bricks' application in robotics at the level of higher education, reviewing 36 out of 1,363 papers drawn from multiple databases. They found that LEGO® was used for teaching programming, interdisciplinary content, participation in tournaments, robotics, and computational thinking and showed successful results at different educational levels, such as K12, undergraduate, and graduate levels (Souze et al., 2018). However, Calderón and Ruiz (2015) indicated, based on a systematic review of serious games in software project management, that only 2% of 102 journal papers used LEGO® as a learning tool. This implies that LEGO® is not a popular learning tool in certain subject areas. Furthermore, most of the systematic review papers point out that more rigorous research is required to find a substantial impact of LEGO® on education (Lindsay et al., 2017; Xia & Zhong, 2018; Souza et al., 2018). There is no standardization of teaching practices or methodologies in the use of LEGO® in education; therefore, it is important to investigate various educational contexts to examine the impact of LEGO® usage and to determine the best teaching practices (O'Brien, 2019; Souza et al., 2018).

The remainder of this paper is organized as follows. Section 2 describes the review process adopted in this study. Section 3 provides the search results and analysis highlighting the study focus (subject), method (classroom exercises, experiments, workshops, lectures, etc.), and application target (individuals or groups). It also contains a discussion on the typology of LEGO® bricks' application in education. Finally, section 4 concludes the research and refers to further research.

2. Methodology

For our preliminary search, we used electronic resources from NUS Libraries and Google Scholar via keyword searches using the terms LEGO®, Education, and Training. The purpose was to obtain an overview of resources in the broader fields of education and training. Upon discovering a huge number of results, we decided to focus specifically on four databases: Web of Science, Education Resources Information Center (ERIC), ScienceDirect, and ResearchGate. Both Web of Science and ERIC were the principal search systems. We chose Web of Science as it indexes high-impact journals in the field of education. Furthermore, its numerous filters and search functions facilitate efficient searching. ERIC was chosen as it is "an authoritative database of indexed and full-text education literature and resources" (EBSCO, 2021). We retrieved a total of 497 publications (314 proceedings, 180 articles, five early accesses, four meeting abstracts, and three reviews) from Web of Science, whereas we retrieved 113,760 scholarly articles from ERIC. We used ScienceDirect and ResearchGate as supplementary search resources. Based on this preliminary set of publications, we further narrowed the search based on the following criteria:

- Studies exploring the use of LEGO® in higher education
- Studies that used LEGO® as a learning tool in education programs or curricula
- Studies in the English language
- Studies published between 2000 and 2020 (the last 20 years)
- Published journal articles and conference papers only

Regarding research types, both quantitative and qualitative studies were included in this review. We found 105 papers from the Web of Science, 112 from ERIC, 62 from Science Direct, and 19 from ResearchGate. We further narrowed down our search to papers that contained "LEGO®" in the title only to be more focused and intentional in our exploratory review.

Finally, we closely reviewed these articles to ensure that there was no duplication in multiple sources produced by the same author (e.g., a journal article and a book chapter, or a dissertation and a journal article). Finally, we had 84 relevant sources consisting of a mixture of conference papers and journal articles. Please note that we did not include any dissertation research papers in the literature review.

We began to review the 84 sources through data extraction involving selecting and entering information from each source for storage (Title, Author(s), Year, Journal, Research Focus, and Research Method). Next, the reviewers made additional judgments regarding the source content. In the third round, the introduction, methodology, and conclusion sections of the 84 sources were read. We also analyzed the titles and abstracts of these papers with reference to the above search criteria. Studies that involved the use of LEGO® in teaching and learning were included. In this final phase, 26 papers were selected as samples for a subsequent literature review capable of answering the research questions. A summary of the 26 papers is presented in Table 2.

3. Results and discussions

3.1 Classification of articles

Based on the literature review, we identified two major trends in LEGO® brick applications in higher education: applying LEGO® as a learning facilitation tool and applying it as a thinking facilitation tool. When LEGO® is introduced as a learning facilitation tool, the outcome is more or less predictable for educators because there is a certain subject to teach and the educational goal is defined (Hussain, 2006;

Table 1: Summary of the search

Selection Strategy	*Results from the Search*
Round 1: Keyword search – LEGO® & Education & Training	298
Round 2: Keyword search – LEGO® & Higher Education	84
Round 3: Introduction, Methodology, & Conclusion	26

Table 2: List of the reviewed papers and summary

Authors (y)	*Study focus*	*LEGO® Type*	*Methods applied*	*Target (Number of participants in a group)*
Steghöfer et al. (2017)	Project management (teaching scrum)	LEGO® City	Action research through workshops	Group (5 to 8)
Müllera et al. (2015)	Production engineering	Mindstorms	Factory management game	Group (N/A)
McFall & Scholz (2011)	Engineering design	Mindstorms	Classroom-based comparative study between teams with and without LEGO® Mindstorms	Group (4)
Zenk et al. (2018)	Innovation and entrepreneurship	LSP	Classroom-based activity	Group (3 to 4)
Anthoney et al. (2017)	Resilience concept	LSP	LEGO® SERIOUS PLAY® and concept map	Individual and Group (4)
Peabody & Turesky (2018)	Shared leadership	LSP	Classroom-based activity	Group (3 to 5)
Ringwood et al. (2005)	Engineering design	Mindstorms	Lectures and workshop using LEGO® Mindstorms	Group (3)
Graham & Alison (2017)	Threshold concepts and liminality	LSP	Classroom-based activity using LEGO® SERIOUS PLAY®	Individual and Group (N/A)
Tseng (2017)	Fostering narrative identity	LSP	Classroom-based activity using LEGO® SERIOUS PLAY®	Group (6 to 8)
Kim & Jeon (2009)	Embedded system	Mindstorms	Classroom-based activity	Lecture size of 80 undergraduates
Papanagnou et al. (2018)	Effective communication	Normal bricks	Interactive workshop	Individual and Group (N/A)
Danahy et al. (2014)	Learning experience	Mindstorms	Use LEGO® Robotics in lessons	Individual
Buckle (2015)	Metaphorical learning	Normal bricks	Interactive workshop	Individual and Group (N/A)
Bonneau & Bourdeau (2019)	Collaborative work	Normal bricks	Video recording and feedback discussions	Group (4)
Lindh & Holgersson (2005)	Problem solving	Normal bricks	Combination of observations, interviews, and experiments using LEGO® bricks	Group (3 to 4)
Wan & Chiu (2002)	Creativity	Normal bricks	Experimental design using LEGO® bricks	Individual
McCusker (2019)	Effective communication in teams	LSP	Case study of a classroom-based activity using LEGO® SERIOUS PLAY®	Individual and Group (N/A)

Dann (2018)	Marketing education	LSP	Observational study, LEGO® SERIOUS PLAY®	Group (3 to 6)
Stephan & Sonnenburg (2018)	Design thinking	LSP	Experimental design using LEGO® SERIOUS PLAY®	Individual and Group (N/A)
James (2013)	Creative arts	LSP	Observational study, LEGO® SERIOUS PLAY®	Individual
Peabody & Noyes (2017)	Reflective practice	LSP	Interviews, LEGO® SERIOUS PLAY®	Individual and Group (N/A)
Moreau and Engeset (2016)	Problem solving/ Creativity	Normal bricks	Experimental design using LEGO® bricks	Individual
Šāblis, Gonzalez-Huerta, Zabardast, & Šmite (2019)	Lesson on global work	Normal bricks	Observational study, using LEGO® bricks	Group (4 to 5)
Rainford (2020)	Creative confidence	Normal bricks	Interviews, using LEGO® bricks	Individual
Beisser & Gillespie (2003)	Teaching and learning course	Microworlds	Case study, using LEGO® bricks LEGO® Microworlds	Group (5)

Source: Papers selected from Web of Science, Science Direct, ResearchGate, and ERIC. LSP refers to LEGO® SERIOUS PLAY®.

Baratè, 2017). On the other hand, when LEGO® is introduced as a thinking tool, the outcome is highly likely to vary according to who is participating in the work. Furthermore, students are assigned to an individual LEGO® activity in some educational cases (Lindsay et al., 2017), while in other cases, they are assigned to collaborative work using LEGO® bricks (Dumitraşcu et al., 2014; Jensen et al., 2018). This suggests that LEGO® applications can be further classified according to the number of students engaged in LEGO® activities.

Therefore, we developed a typology of LEGO® brick applications in education, as shown in Figure 1. The purpose of this typology is for educators to find an appropriate way to introduce LEGO® bricks into their education. It consists of four quadrants that are classified by two axes: the aim of the application and participants in action. The aim of the application is educators' intention to introduce LEGO® bricks into their teaching activity, either for letting students learn or think. These aims sometimes overlap, but we think that it is possible to highlight the distinction in the initial teaching intention. Participants in action is the number of students engaged in an activity with LEGO® bricks. When a student is assigned a LEGO® activity alone, their learning or thinking processes and their outcome are more likely to be personal. On the other hand, when a group of students is assigned to a group collaborative work with LEGO®, their learning or thinking processes are rather interpersonal. In other words, the process and outcome are shared among group members. Each of the quadrants represents different types of LEGO® brick application in education: type 1 is theory, type 2 is practice, type 3 is reflection, and type 4 is communication.

3.1.1 Type 1: Theory

This is when students learn theory or basic knowledge in a certain subject using LEGO® bricks. For example, Fillippov et al. (2010) introduced LEGO® for teaching control theory in robotics, and Zaldivar et al. (2019) for teaching optimization fundamentals. In these cases, LEGO® bricks were used to provide experiential learning opportunities for novice learners. In another study, Buckle (2015) used LEGO® in a language game to create metaphors and engage learners through all their senses so that they could construct their own understanding. When there is a lack of fundamental knowledge in students, the introduction of LEGO® bricks functions as a shortcut to intuitively understand the basic principles behind a theory. Furthermore, LEGO® bricks are used to learn non-technical skills, such as leadership (Peabody & Turesky, 2018) and team building (Dann, 2018). The fundamental theories of these non-technical domains are difficult to describe in words. Thus, it is more effective to provide active learning experiences by doing something with LEGO® bricks.

3.1.2 Type 2: Practice

This is when students put their knowledge into practice through engagement in hands-on activities with LEGO® bricks. Robotics is a field in which LEGO® is widely applied as a group learning tool. LEGO® Mindstorms are a popular learning product that many universities have introduced to teach introductory robotics and programming courses for first-year engineering students (McFall & Scholz, 2011; Zaldivar et al., 2019). Freshmen from Sungkyunkwan University in Suwon, Korea said that LEGO® Mindstorms helped them understand the components and characteristics of embedded systems, such as dedicated software, dedicated input and output devices, the relationship between software and hardware, and the corresponding constraints (Kim & Jeon, 2009). It is also used in high school and junior high school education (Atmatzidou et al., 2008; Kazakoff et al., 2013). The hands-on, participative learning experiences have intuitive, self-learning effects on students, who do not need to fully understand the theoretical background of robotics and programming in advance (Ringwood et al., 2005).

3.1.3 Type 3: Reflection

This is when students think about a certain subject with the help of LEGO® brick modeling and visualization. In other words, LEGO® bricks are used as a thinking facilitation tool when an issue is conceptually unclear for students. For example, Anthoney et al. (2017) used LEGO® bricks to facilitate students' understanding of the concept of resilience, and Graham and Alison (2017) introduced the LEGO® Serious Play® (LSP) method to explore threshold concepts. When an issue is personally unclear, LEGO® bricks can help one elaborate on one's own ideas through visualization. LSP is a systematic methodology that facilitates a series of personal and group-thinking processes. It is effective for visualizing the unconscious perception of unclear issues using a three-dimensional model-building process. Many researchers have used LSP combined with other thinking methods, such as design thinking (Primus & Sonnenburg, 2018) and systems thinking (Graham & Alison, 2017). In another study, Tseng (2017) used LSP as an intervention to strengthen economically disadvantaged college students' capacity to purposely integrate their life experiences; that is, to enhance their narrative identities.

3.1.4 Type 4: Communication

This involves students exchanging ideas through model-building activities with LEGO® bricks. In other words, the LEGO® bricks function as a communication catalyst. For example, students are initially assigned to an individual LEGO® activity and are required to explain the outcome of collaborative group work using LEGO® bricks at the end (Dumitraşcu et al., 2014; Lindsay et al., 2017; Jensen et al., 2018). This is often combined with group-oriented activities, such as innovation design projects (Zenk et al., 2018) and creative problem-solving (Wengel et al., 2016). Such group projects often become more difficult to manage owing to the diversified viewpoints within groups. Model building with LEGO® bricks is effective for facilitating interpersonal communication by visualizing and identifying gaps among the group members. A group of medical students underwent an interactive workshop using LEGO® to help them practice communication skills (Papanagnou et al., 2018). The workshop was well received. Students made requests to have similar sessions throughout their training to better support the development of effective communication skills.

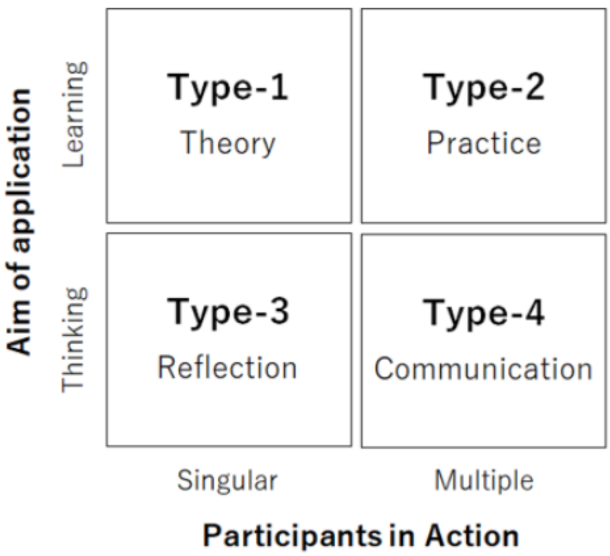

Figure 1: Classification of LEGO® brick applications in education

4. Conclusions

This study demonstrated that the use of LEGO® in teaching and learning is diverse, encompassing learning facilitation, thinking facilitation, individual applications, and group applications. A simple typology was proposed based on our findings, classifying 26 research articles into 4 quadrants, with each quadrant representing different types of LEGO® bricks application in education: type 1, theory; type 2, practice; type 3, reflection; and type 4, communication. This classification is represented using two axes: the aim of the application and participants in action. The purpose of this simple typology is to provide a clearer picture of the various educational contexts of LEGO® usage in higher education and to identify trends in teaching practices.

A limitation of this study is the focus of the review on the use of LEGO® bricks in teaching and learning in the higher education context. As this study focused only on higher education contexts, future studies could include the use of LEGO® bricks at other educational levels, such as professional development courses or pre-university levels. Future studies could also investigate the effectiveness of LEGO® bricks in fulfilling different educational goals. Another limitation of this study relates to the use of qualitative methods (e.g., observational and case study methods) in the majority of the selected research articles. Future studies could strive to equally represent both quantitative and qualitative studies so that the exploratory analysis could generate an understanding of the differences in the findings and learning processes. Another limitation of this study is the discussion section of this report based on the research articles selected, which mainly focused on reporting and classifying what was done in the past. Future extensions of this paper could consider expanding the discussion to compare different types of research article based on the typology presented in this paper or the impacts of LEGO® on teaching and learning.

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