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# A Sustainable LEGO Adaptation of Billington's Lean Manufacturing Pedagogical Activity

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**Abstract.** As the business school curriculum moves to more interactive learning methodologies such as flipped classrooms and student led discussion, faculty need to be more creative in keeping students engaged in the learning environment. In this paper, we discuss our experiences using the pedagogical game from the literature "A Classroom Exercise to Illustrate Lean Manufacturing Pull Concepts" (Billington 2004), and a modified, more sustainable adaptation of the game that we developed. Billington's (2004) activity uses printer paper to make paper airplanes, while our version deploys reusable LEGO pieces to build cars. The game requires active participation and or observation on the part of the students, and survey results indicate positive perceptions of learning outcomes from the exercises. The aggregate scores for the LEGO adaptation are statistically significantly higher than for the aggregate paper airplane scores. A pre- and post-exercise quiz was given to the students, with both male and female students showing a significant score improvement in the post-exercise quiz.

**Keywords:** active learning, pedagogical exercise, push versus pull production, assembly lines.

## 1. Introduction

In the fall of 2016, Bryant University opened a new academic building named the Academic Innovation Center that facilitated interactive learning. The building includes five spacious tiered classrooms with whiteboard walls for lecture style courses, five flat classrooms with whiteboard walls and moveable furniture, and a large open area (the Innovation Forum) with moveable furniture. The new building presented an opportunity to build active learning pedagogical exercises into the curriculum for Operations Management (OM) courses. Numerous OM pedagogical games have been proposed in the academic literature and a review of those games is beyond the scope of this paper. Chen (2019) conducted a review of education games in the decision sciences and created a searchable spreadsheet as a tool for instructors who want to include pedagogical games in their curriculum. The spreadsheet is available at https://onlinelibrary.wiley.com/doi/full/10.1111/dsji.12245 under Supporting Information.

In this paper, we discuss our experiences using the game "A Classroom Exercise to Illustrate Lean Manufacturing Pull Concepts" (Billington 2004) and present a sustainable adaptation of the game we developed. In the Billington (2004) game, students build airplanes using printer paper, while in our version students assemble cars with LEGO pieces.

We switched the product from paper airplanes to LEGO cars primarily due to the lack of sustainability of using paper. Most students are familiar with the LEGO building system and assembling LEGO pieces is an easy task to perform. And the use of multiple parts allows flexibility in changing the number of workstations to accommodate different class enrollments.

Teaching lean production concepts is relevant to business students because most business processes follow a flow that is similar to that of making a product. Dennis (2007) discussed how a pull system controls work-in-process and improves flow, allowing the company to reduce batch size and queue lengths. This in turn lowers operating expenses such as holding costs for raw materials and work-in-process and reduces defects and throughput times. The objective is "make one - move one", or in a service environment "serve one - move one" (Dennis 2007). Monden (1998) points out that in a JIT (just-in-time) production system "the inventory carrying cost will be diminished and the ratio of capital turnover will be increased" (p. 5). Hence students can apply lean production concepts to the service environment and connect them to finance and accounting performance measures.

Teaching and learning methods are increasingly moving away from teacher-centered approaches and towards student-centered ones, like game-based teaching, to enhance learner motivation and engagement (Alsawaier 2018; Cheng 2021; Ninaus *et al.* 2019). Consequently, we anticipate a rise in the use of educational games in business classes. A consideration is the significant paper waste generated by some of these games. This study proposes a sustainable alternative to replace paper and it is imperative in various aspects:

1. Environmental Impact: The production and disposal of paper has a notable impact on deforestation, water use, and greenhouse gas emissions. Choosing a sustainable alternative for the educational game could lessen its environmental impact and support worldwide initiatives to address climate change.

2. Cost-Effectiveness: While the initial investment in LEGO might be higher, the long-term savings due to durability and reusability can make economic sense.

3. Educational Value: Integrating sustainability into the classroom experience can serve as a practical demonstration of environmental responsibility, educating students about the importance of

sustainability and influencing their attitudes and behaviors outside the classroom. Integrating sustainability into business higher education is critical for enhancing environmental awareness within the corporate sector (Dima & Meghisan-Toma 2018; Rusinko 2010; Stephens *et al.* 2008). Our study by providing a sustainable alternative helps to bring awareness to business students.

4. Institutional Goals: Many educational institutions are bound by sustainability targets that aim to reduce waste and promote environmental-friendly practices. Limiting the use of paper for educational games aligns with these goals and ensures compliance with such standards.

The outline of our paper is as follows. We first briefly discuss the literature on sustainable pedagogical games and the literature that illustrates the use of LEGOs in pedagogical exercises. Next, we introduce the Billington (2004) version of the game and our LEGO modification. Then we present our student perception survey results for the two versions of the game, and we finish with concluding thoughts.

## 2. LEGO Games in the Literature

Educational operational games, such as role-playing games and simulations, have been shown to create an engaging and interactive learning environment that enhances student learning outcomes (Beatty *et al.* 2021; Zeng *et al.* 2020). However, educators must also consider the environmental impact of the materials used in these games, which typically include paper, cardboard, and plastic. To address this concern, sustainable practices should be implemented in these games (Gatti *et al.* 2019; Jääskä *et al.* 2021). Yet, finding sustainable alternatives remains a challenge, and more research is needed to identify effective methods for integrating sustainability into pedagogical games. In addition to the development of educational games designed specifically to teach sustainability (e.g., Escudeiro *et al.* 2022), there is growing recognition of the need for sustainable changes in gamification in education (Yoo *et al.* 2017). In this study, we introduce a sustainable LEGO modification to a pedagogical game on lean manufacturing pull concepts proposed by Billington (2004) and examine its impact on student learning outcomes.

The use of LEGO blocks to facilitate learning activities in OM was first discussed by Ammar and Wright (1999). They presented a game to support linear programming concepts where students optimized the number of tables and chairs to produce. In this exercise, the LEGO blocks serve as a prop to replicate real products. A second LEGO-based exercise utilized LEGO pieces

to determine task times to build a model airplane and then to create a balanced production line for a given cycle time (Ammar & Wright 1999). Satzler and Sheu (2002) described several LEGO group projects to facilitate learning in large (~300 students) introductory OM classes. Concept areas covered included product development, workforce management, process/workstation design, materials requirements planning, and statistical quality control.

DUPLO blocks were used by Fish to demonstrate assembly line balancing (2005) and push versus pull (2006) by having her students build abstract dogs from the blocks. For both games, over 90% of students responded favorably to a question on the continued use of the game to assist in learning.

We identified two articles where LEGOs were used in a supply chain context. Drake and Mawhinney (2006) developed a simulation to introduce business and engineering students to the forward and reverse flows of raw materials, finished goods and information in a multi-tier supply chain. Students used LEGO pieces to build products as they advanced along a supply chain as work-in-process until they reached the customer as a finished good. Reyes (2007) used LEGOs to represent the material being distributed through a supply chain to extend the well-known Beer Game by adding a parallel interaction to introduce students to rationing and gaming effects.

## 3. Paper Airplane Lean Manufacturing Game

Billington (2004) developed the Lean Manufacturing game to illustrate the differences between push versus pull production systems, with a focus on work-in-process (WIP), throughput time, Kanban, bottleneck operations, line balance and worker behavior. The game is comprised of three scenarios where students (workers) construct a paper airplane from a piece of 8 ½ by 11-inch paper. Scenario 1 is a push system, scenario 2 is a pull-3 system and scenario 3 is a pull-1 system. In the pull-3 system, each kanban holds three units of WIP. When a worker notices that the kanban downstream from their workstation is empty, they add their part(s) to the WIP in the kanban upstream from their workstation (also holding three units of WIP). The worker completes their task on the three units of WIP to replenish the empty kanban downstream from their workstation. In the pull-1 system, each kanban holds one unit of WIP. When a worker notices that the kanban downstream from their workstation is empty, they add their part(s) to the WIP in the kanban upstream from their workstation (also holding one unit of WIP). The worker completes their task on the single piece of WIP to replenish the empty kanban downstream from their workstation.

Four workers in a serial line layout make specified folds to the paper to create the airplane. However, worker 3 has more tasks than the other workers and therefore becomes the bottleneck in the production process. Different