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'All they do is win': Lessons learned from use of a serious game for Circular Economy education

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ABSTRACT

This paper aims to explore how learning about Circular Economy (CE) may be facilitated through the use of the serious game *In the Loop*. Despite the growing literature base related to CE, academic reflection on education for a CE is currently limited. *In the Loop* was developed to provide an experiential learning situation for educating about material criticality and CE. This study reflects on the use of the game with engineering students pursuing higher education. Seventy-one reflections, written after students played the game, were qualitatively coded through the use of a-priori coding. This paper presents the findings from analysis of four themes: Gameplay, Systems Thinking, Material Criticality, and Realism/Real World Connection. Use of the game encouraged students to think holistically and reflect on material criticality. Students highlighted the importance of adopting strategies, including CE concepts, to address resource challenges, with many reflecting on how their own actions and abilities could play a role. Moreover, the study suggests *In the Loop* has broader relevance than engineering education alone and appears to confirm previous research on the benefits of using games to facilitate systems thinking.

1. Introduction

Today's society is faced with a growing number of wicked problems related to resources and production. Increasing global demand of some engineering resources, growing populations, and price volatility has given rise to concerns over future access to resources (Allwood et al., 2010; Ayres and Peiró, 2013; Greenfield and Graedel, 2013). At the same time, product lifespans are decreasing in length (Wang et al., 2013), especially for many products containing 'critical' materials (European Commission, 2014; Defra, 2012; US Department of Energy, 2010). As material criticality will become a growing concern for future engineers (Köhler et al., 2013), there is a need for developing societal-aware engineers who understand these challenges (De Graaff and Ravesteijn, 2010).

As a kind of catch-all philosophy, Circular Economy (CE) has been positioned as a solution space for addressing these growing resource concerns as the concept encourages a decoupling of resource usage from economic growth (Ghisellini et al., 2016). Applying CE in practice, however, requires a systemic transformation from the current linear economy, particularly in how products and services are designed, produced, and sold. In order to lead this system transformation, new design skills must be embedded into design and engineering education, with holistic and transdisciplinary thinking playing a key role (Andrews, 2015; Moreno et al., 2016).

Experiences from related teaching streams (particularly education for sustainable development (ESD)) have shown it is quite a challenge to educate future engineers in this manner as it demands a departure from the current disciplinary and subject-focused teaching that predominates current educational paradigms, particularly in engineering education (Kay and Foster, 1999). Simply integrating sustainability topics into existing courses is not sufficient (Sterling, 2005), as the current paradigm's approach is too reductionistic to handle wicked problems. Instead, students must learn to employ systems thinking (Kay and Foster, 1999; Meadows, 2008; Sterling, 2004) to fully comprehend both the drivers behind the problems as well as the possible solution space. Furthermore, in addition to this key sustainability competency (Wiek et al., 2011), to be truly sustainable future engineers, students must also build an awareness of societal (Azapagic et al., 2005; Pritchard and Baillie, 2006) as well as economic (Fitzpatrick, 2016) aspects.

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To address the challenges related to material scarcity and encourage CE solutions, a serious board game called 'In the Loop' was developed (Whalen, 2013; Whalen and Peck, 2014). Games have increasingly gained credibility in scientific literature (Star, 2010; White et al., 2010) as a way to bridge the communication gap between different stakeholders (van Pelt et al., 2015) and support sustainability education (Dieleman and Huisingh, 2006). We aim to evaluate the game's application within the context of engineering education by exploring students' experiences of using *In the Loop* through a qualitative document study. We hypothesize the game is a useful tool for teaching about the benefits and complexity of CE, as playing increases students' understanding of material criticality and ability to propose potential solutions. The findings of this study have potential implications for future research on education for CE and ESD.

2. Background

2.1. Circular Economy in education

Previous and existing education initiatives in materials, engineering, design, and business have focused on CE (Leiden University, 2014; TU Delft, 2015; Aalto University, 2016; EIT RawMaterials, 2016; Politecnico di Milano Graduate School of Business, 2016; United Nations University, 2016) and CE has also been a recurring theme in discussions at recent educational conferences (EESD, 2016; Materials Education Symposium, 2016). However, even with this clear and growing interest in education for CE, few studies have reflected on how to approach and embed CE concepts in education. Andrews (2015: 313) concluded designers, in contrast to the past, "must now respond to very different social, economic and environmental needs and adopt a holistic approach to problem solving" which considers CE concepts such as maintenance, repair, reuse, remanufacturing, refurbishing (often referred to as the 'inner circles') and recycling (also known as the 'outer circle') (Ellen MacArthur Foundation, 2013; Geissdoerfer et al., 2017). Like Andrews (2015), Moreno et al. (2016) also focused on designers, presenting a conceptual framework of ten points to consider when designing for CE; echoed in these ten points are four main themes: systems thinking, economic aspects, societal awareness, and experiential learning.

In contrast to education for CE, the body of literature on ESD has been a growing area of focus for some time. As CE overlaps with sustainable development and both topics are transdisciplinary (Sauvé et al., 2016), takeaways from existing ESD literature are believed relevant for CE education. Much of this ESD literature is focused on how to implement the topic in curriculum and illustrates challenges associated with embedding this type of thinking in education (Ashford, 2004; Charnley et al., 2011). Implementing ESD in educational practices can potentially be viewed as a threat to core curriculum, especially if the action is interpreted as trying to 'replace' or 'add' additional content (Jones et al., 2008). Furthermore, in traditional teaching models, different subjects are siloed and not usually connected, unlike sustainable development and CE which bridge multiple curricula.

In training students to address the complex issues of the twenty-first century, ESD advocates moving away from traditional discipline- and analysis-oriented teaching focused on the 'right' answers (Shephard, 2008) and adopting a wider-perspective instead (Gattie et al., 2011). Ways of mediating experiential learning related to reality and encouraging holistic thinking (characterized by critical and systems thinking) are therefore encouraged (Dawe et al., 2005). Using systems thinking teaching methods, for example, can help students "to see the greater perspective"' (Peet et al., 2004: 280) and consider interdependencies, system boundaries, internal and external environmental influences, causes and effects of system changes, complexity, multiple stakeholder perspectives, and causalities. Serious games have received attention for experiential, systems thinking-focused learning as they provide a safe space for students to experiment with a dynamic, interactive system representing reality (Crawford, 1984).

While the specific effects of using games for learning can be difficult to quantify, games utilize two stages of learning – active experimentation and concrete experience – not usually addressed by common teaching methods but nonetheless important for learning from a pedagogical point of view (Kolb, 1984). In reflecting on the use of games to illustrate the trade-offs and tensions in sustainability ethics, Sadowski et al. (2013) found students became active and emotionally invested participants and increased their group tacit knowledge. Other studies also tout the benefits of games in sparking critical thinking and experiential learning. For example, Ke (2009) found games to be beneficial in assisting high-order thinking such as planning and reasoning. Sitzmann (2011) pointed in the same direction, acknowledging the advantage of games' active learning situations, but also emphasizing the importance of using games within a broader context, rather than as stand-alone activities. Dieleman and Huisingh (2006)'s reflections of using serious games in ESD resonate this point, arguing for debriefing sessions after the game to not only provide additional context and facilitate participants' learning, but also to share and compare experiences amongst participants.

2.2. Description of In the Loop

The serious game *In the Loop* (Fig. 1) was created to facilitate experiential learning about material criticality and CE concepts. *In the Loop* is a turn-based, serious board game intended to increase players' recognition of the benefits of CE approaches by illustrating the causes of, potential effects from, and possible solutions for addressing material criticality. The game centers on twelve elements[1] from the European Commission's 'critical raw materials' list (Whalen and Peck, 2014).

The material criticality viewpoint was selected as it is one of the main motivating drivers behind establishing a CE (Lieder and Rashid, 2016). Material efficiency strategies are advocated not because of an absolute shortage of ores (Allwood et al., 2011), but rather because of concerns over supply and demand stemming from a variety of factors not limited: to increased product complexity (Greenfield and Graedel, 2013); lack of acceptable substitutes (Graedel et al., 2013); and limited geographic concentration of materials (European Commission, 2010; Melcher and Wilken, 2013; Scotland & Northern Ireland Forum for Environmental Research, 2011). As companies and countries undertake initiatives to safeguard precious resources and reduce potential economic risks (Peck et al., 2015), multiple solutions to dealing with these resource challenges have been suggested in addition to CE. These include using material substitutes or more abundant materials (Diederen, 2009), increasing supply chain transparency (Candelise et al., 2012), and implementing government interventions such as the creation of national strategic reserves or bilateral trade agreements (Massari and Ruberti, 2013). Table 1 summarizes how *In the Loop's* game elements and gameplay embody these aspects of material criticality and CE concepts.

In the game, each player (or team of players) takes on the role of a manufacturing company CEO and aims to be the first company to reach seven 'Progress Points'. These points are awarded by producing products and making resource-efficient strategic decisions. To produce products (e.g. printed circuit boards, LED screens, photovoltaic cells), players must first mine and bid for certain materials (e.g. neodymium, tungsten, gallium). After production, products and materials are immediately confined to the 'Junkyard' as players begin the game with linear business models.

As play progresses, players face competition over the same materials and struggle to collect enough materials in order to produce products

[1] These materials are as follows: Antimony, Beryllium, Cobalt, Gallium, Germanium, Indium, Magnesium, Niobium, Rare Earth Elements (group), Platinum Group Metals (group), Tantalum, and Tungsten.