Constructionism in the Light of Computational Creativity

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Various Artificial intelligent methods were developed with inspiration from human practices to optimize existing solutions or propose new valuable ideas. Computational Creativity is one of the emerging young fields that utilizes AI techniques to build results that are creative, novel, and represents the most impressive form of AI today. It impacts almost all disciplines and leads to continuous reports in the media, e.g. about AI generated images, stories, and music. If constructionist learning constitutes (re)constructing meaningful products students' find in the world around them, wouldn't the future of constructionist learning involve enabling students to create their own computational creativity system? In the following paper, we propose such a constructionist learning approach where students learn about and draw their own conclusions on CC systems. Students do not only learn powerful ideas of CC systems, but also reflect and apply the building blocks of the subject domain they are dealing with. Hence, they may better understand the world around them.

Keywords and Phrases: Computational Creativity, Constructionism, Artificial Intelligence.

1 INTRODUCTION

Constructionism is a learning theory that is denoted with the idea of learning by constructing (Papert, 1968). It is a student-centered approach that includes learning through discovery, and relying on information that students already know to gain knowledge. It also encourages project-based learning with guidance from teachers to lead students into constructing projects of their own, and shaping their different ideas into producing something they are learning about.

The main essence of constructionism is about students building their knowledge structures, allowing students to think in their own way and not to follow a predetermined pipeline to gain new knowledge. Having modern technology-based techniques could inspire and support students to build nearly optimal knowledge structures for topics they are learning about. It could also provide modern learning experiences to encourage them to be more resilient and utilize previous knowledge in gaining new knowledge, as opposed to passively receiving information (Kafai, 1996).

Learning is associated with creativity. Considering teaching practices that allows the students to be creative, make students more resilient and autonomous in their life, and that requires adopting newest trends and technologies in teaching environments (Cross, 2012). Vygotsky defines creativity as anything new that humans produce, whether it's a product, a thought or a mental structure (Vygotsky, 2004). He also views the creative process as a collective process that re-combines pre-existing discoveries or knowledge items into a new discovery. This can be highly relatable and important in education, to understand how students learn new concepts or build new artefacts.

Computational Creativity (CC) is a new area of research that proposes several ideas related to simulating human's creative behavior in many areas, such as developing music (Romeike, 2007), narratives (Issa, 2019), culinary arts (Issa, 2021), etc. Its main goal is to produce creative artifacts by simulating human's way of producing creativity. Boden has argued that considering familiarity; which is based on human's previous experience, novelty; that is the non-deterministic addition to human ideas, and value; which is the usefulness of the result in the real world, are three essential components in order to create a CC system that produces creative artifacts (Boden, 2004). Building these systems does not only mimic human creative productions, but allows us to break down creative artifacts around us, and explore human's creative minds. It could also inspire in multiple domains to model their development of creative results.

In education, CC could present a new approach in constructionism, which supports the idea of learning by construction. Human's creative imagination is goal-oriented, and thinking about concepts, makes the concepts explicit in the human mind (Lindqvist, 2003), and that allows the person to connect concepts and ideas together. Building a CC system, allows students to break down concepts and artifacts and make them explicit, which leads to students thinking creatively, towards a goal of creating something new. This could participate in building the skill of learning-how-to-learn by breaking down the concepts and artifacts into basic blocks, extract patterns, and rules and constraints. Then construct a new result that is novel and valuable, and reflect on the process. This helps students not only to learn about the topic they are studying but the computational method of constructing CC systems that utilize AI.

2 COMPUTATIONAL CREATIVITY IN CONSTRUCTIONIST LEARNING

2.1 Computational Creativity Systems in Education

CC systems are created to mimic human creativity in certain fields, using AI-based techniques to produce results that are held to be creative, and to enhance human's creativity (Mateja, 2021). From different domains, a general pattern could be analyzed and rules could be extracted, to guide the process that aims at building problem-solving methods that are inspired by human creativity to achieve novelty and familiarity (Jändel, 2013).

Many researchers have studied using CC in education, for example, (Marbach-Ad, 2020), explored the potential of a CC approach in supporting students' learning of physics. They developed a computer-based platform that enabled students to create interactive physics simulations, and found that this approach led to improved engagement and understanding of physics concepts. Also, (Ramírez-González, 2020), used a CC approach to support students' learning of mathematics. They developed a system that generated creative problems for students to solve, and found that this approach led to improved engagement, creativity, and mathematical understanding, (Johnson, 2012) followed the same approach in teaching history.

CC systems are successfully and predominantly used to foster learning, but students basically only use these tools like "magic tools", without knowing how the outcomes are created and which building blocks of the subject domain lead to the results. We find an opportunity to benefit from the idea of constructing computational creativity systems and making this process explicit under the umbrella of constructionism, as students will not only construct CC systems to learn from the final output, but also learn among the process of creating the system, which will sharpen their learning-how-to-learn skills.

2.2 Enabling Students to Create Their Own Computational Creativity System

Many researchers in education discussed various approaches to foster students' creativity by applying innovative teaching methods (Siew, 2014), or by modern techniques that involve AI and technology, such as interacting with robots (Ali, 2019; Yang, 2020). Vygotsky implied that creativity is both the goal and the mean for the development of students (Vygotsky, 2004), and here, we present a new approach in fostering students' creativity by enabling them to create CC systems in a constructionist learning approach.

Constructionist learning implies that students learn best when creating something that can be shown and be proud of, and something which represents a certain concept. By creating CC systems themselves, not only can the motivation of the students be addressed, but they also get the chance to learn and understand about AI. Previously, it was proven that utilizing computer-based systems and AI, allowed students to learn about AI and computing in general and develop skills in this area (Ali, 2019). Furthermore, creating a CC system requires a learner to really reflect on the subject domain (e.g. language, music or cooking) in which the CC system is to be built for, hence fosters learning not only about AI but also might foster the understanding of the subject domain.

The process of creating a CC system allows learners to learn how to break down the subject they are learning, into a generalized pattern of blocks, which will make them more creative, increase their ownership over the content they are learning, have individualized experiences, allow them to construct their own mental models of topics they are learning, learn how to learn further concepts in the same approach, and learn about building computational creativity systems which is a very impressive form of AI systems. This would also speed up the process of reaching a deeper level of learning by creating these creative products (Forehand, 2010). Figure 1 highlights the process of CC to achieve a creative product.

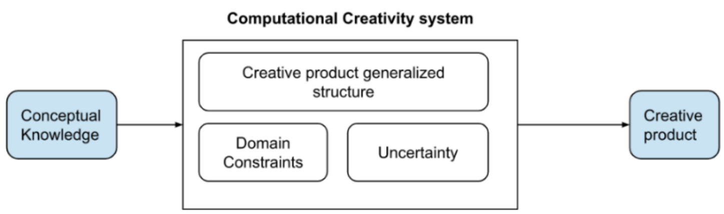

Figure 1: Computational Creativity Process

CC systems are created by analyzing the components of existing artifacts and understanding the constraints that determine how this artifact is created. Let's take culinary arts for example, the first author in (Issa, 2019), proposed a CC system that creates novel food recipes.

In order to create a new food recipe in a computational creativity system, the basic components of food recipes should be realized, which are food ingredients, then, a pattern is extracted of blocks of food ingredient categories that are put together, such as spices, vegetables, meat products, etc. Then, understanding the constraints of which ingredients go together. Furthermore, implementing uncertainty using for example, probabilistic models to model random objects, or random constraints. The last step is to evaluate the product to understand the value and novelty it brings to the audience, and reflect on the process of creation. Evaluation mechanisms could help students orient their creations towards something that is usable and novel, so evaluation can be designed around the main rules of the domain, such as food-pairing hypothesis rules of ingredients compatibility, and the acceptance of this new creative product among the related audience.

Putting this in an explicit form in a constructionist teaching approach will teach students to deconstruct existing artifacts, extract patterns, understand the constraints of creating an artifact, include uncertainty factor, and evaluate the results. It will also teach them to use AI techniques according to the CC system they are creating. For example, using probabilistic models, or rules, simulations, algorithms, and logic, etc. The teacher's role would be guiding students to get individual experiences in constructing different creative products, and to model their creativity into the system they are creating.

3 DISCUSSION

The constructionist approach revolves around exploration and project-based learning, for constructing artifacts. The CC system demonstrates the artifact being created by students which combines their pre-existing knowledge, and their understanding of existing artifacts in the field. We model this idea in Figure 2, it shows the steps of a constructionist approach to create a CC system. Based on student's pre-existing knowledge, and domain knowledge, students will interpret and deconstruct to identify building blocks of existing artifacts, for example, the building blocks of a music track, or a food recipes, or a short story. Then, students will learn to implement a CC system which is the new artifact, including knowledge, constraints and uncertainty. Finally, students will learn to evaluate the artifact to reflect on its novelty and value. During this process, students will form a deeper understanding of the topic they are learning and understand how existing artifacts are broken down to be explicit and represented on a creative AI-based systems. This forms a practical approach for constructionist learning environments to foster students' creativity through their learning journey.

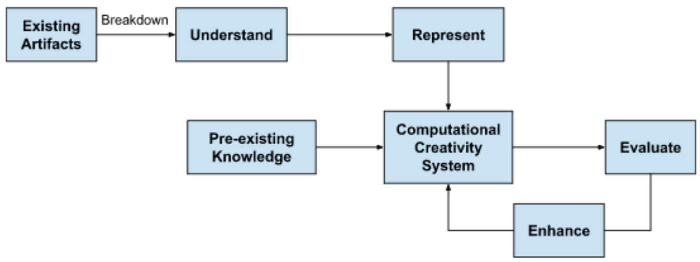

Figure 2: Computational Creativity in Constructionism

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