LITERATURE REVIEW ON THE EDUCATIONAL USE OF PROCEDURAL CONTENT GENERATION ACROSS DISCIPLINES

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1. INTRODUCTION

Procedural Content Generation (PCG) is a method to automatically generate content with little to no human assistance required. It emerges as a promising tool to generate educational content **tailored** to individual learning needs [6].

Additionally, PCG can generate a **wide range of exercises**, enhancing students' **interest and enthusiasm** for topics while **reducing the time and costs** required to develop educational materials [11][27].

This literature study aims to summarize current research on the educational use of PCG across various disciplines, identifying the **benefits and challenges** faced by each and **comparing the applications** of PCG in different domains.

The purpose is to guide future work towards unexplored areas and help understand what challenges are yet to be overcome in the educational use of procedural content generation.

2. METHODOLOGY

This literature review used a **comprehensive approach** to explore the use of PCG in education. The process included identifying, selecting, and classifying relevant studies. Papers were sourced from reliable databases, including Scopus, ACM Digital Library, and IEEE Xplore.

Through group collaboration, a total of **182 papers** were initially identified. **27 papers** were classified as "most relevant" because of their direct applicability to the research question and significant contributions to the field.

Exclusion criteria:
- Not investigating the use of PCG in education
- Presenting a framework outside the scope of PCG
- Redundant with selected studies
- Lacking focus on a specific discipline
- Over 10 years old (except in cases of limited studies in a field)
- Not written in English

3. DISCUSSION

3.1 DISCIPLINE-SPECIFIC BENEFITS AND CHALLENGES

COMPUTER SCIENCE
- **Benefits**: Enhance computational thinking skills and engagement by generating complex puzzles and adaptive game levels tailored to individual learners' needs [20].
- **Challenges**: Adjusting the difficulty of generated problems to match the learner's proficiency level is a major challenge [3].

MATHEMATICS
- **Benefits**: Efficiently generate a diverse range of mathematical problems and exercises, enhancing student's motivation while reducing content creation time [19][27].
- **Challenges**: One challenge is generating exercises that are coherent and adapted to the student's skills [19].

LANGUAGES
- **Benefits**: Create adaptive exercises tailored to individual learning paces, improving reading comprehension and foundational language development [7][6].
- **Challenges**: Generating content that is contextually appropriate and aligns with educational goals presents a challenge [7].

NATURAL SCIENCES
- **Benefits**: Produce varied and interactive learning activities, enhancing enthusiasm and understanding of the concepts [2].
- **Challenges**: One of the key challenges is ensuring the accuracy and educational validity of the generated content [10].

SOCIAL SCIENCES
- **Benefits:** Generate diverse scenarios and case studies to develop critical thinking skills [28].
- **Challenges**: Generating questions that accurately reflect the complexities of this field requires sophisticated algorithms [8].

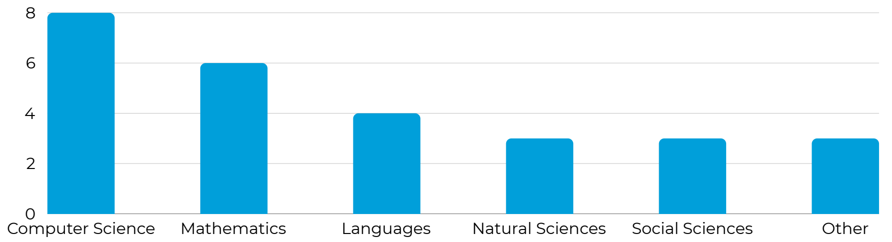

Fig 1. Studies included in this research according to discipline

3.2 COMPARISON BETWEEN DISCIPLINES

SIMILARITIES
- **Adaptive learning activities**: Most disciplines use PCG to adjust education activities based on the student's performance.
- **Enhance engagement**: Another similarity is the role of PCG in enhancing student engagement by generating challenging and diverse content.
- **Efficiency in content creation**: A widely recognized advantage of PCG across disciplines is its ability to reduce the time and cost required to develop educational activities.

DIFFERENCES
- **Type of content**: In computer science, PCG is primarily used to generate serious games; in mathematics, its applications vary. In language studies, it is mostly utilised for early skill activities, while in social sciences, multiple studies used it for immersive learning.
- **Challenges faced**: In computer science and mathematics, the main challenge lies in tuning difficulty. In language education, ensuring the contextual suitability of questions is crucial. In social and natural sciences, guaranteeing educational quality and accuracy is the main challenge.

4. CONCLUSION & LIMITATIONS

Although all disciplines can benefit from the educational use of PCG, **computer science and mathematics** profit the most as these fields often rely on clearly defined formulas and algorithms, which facilitate the generation of educational activities based on these structured principles.

On the other hand, subjects like languages, social sciences, and natural sciences usually involve **context-dependent and nuanced** concepts which are harder to generate accurately with PCG. Broader areas within these branches, such as physics, biology, philosophy, and geography, and other disciplines like the arts, business, and economics, have seen limited exploration, presenting opportunities for future application of PCG.

Future studies should **allocate more time** to ensure a comprehensive analysis of all relevant studies. Additionally, the technical implementation of PCG across disciplines was not investigated in this review and could be a focus for future research.

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