No Patterns in Pattern Recognition: A Systematic Literature Review

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***Abstract*— Pattern recognition is one of the fundamental competencies associated with computational thinking and STEM education. Although much has been written to define computational thinking (CT), we argue that CT is a multi-faceted construct and specific aspects of CT (such as pattern recognition) should be examined. The purpose of this study is to conduct a systematic review of literature on pattern recognition to define pattern recognition as an aspect of computational thinking. The synthesis included the Engineering Village database (Compendex and INSPEC). We searched peer reviewed articles and the keywords, pattern recognition, pattern generalization and education. The initial search resulted in 208 articles. The screening of abstracts more closely resulted in 17 relevant articles, which were then read in detail by two researchers. The review of this pool resulted in two relevant articles, one with a focus on mathematics education and the other one in the context of medical education. Surprisingly there were no articles that examined pattern recognition as part of engineering or computer education. Further research examining specific aspects of CT is necessary.**

Keywords—pattern recognition, pattern generalization, computer education, computing, computational thinking, STEM

I. Background

A. Computationg Thinking is fundamental ability at college and K-12 levels.

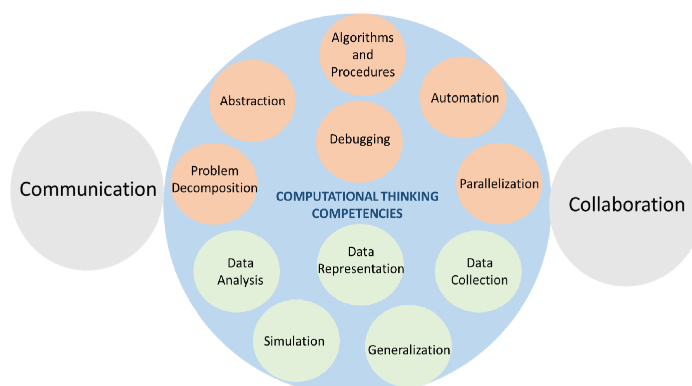
Computational thinking is considered a fundamental ability for students at all levels, not just those aspiring to be computer scientists [1]. Computational thinking is part of college standards for undergraduate education [2] as well as for pre-college [3]. Moreover, some standards such as the Next Generation Science Standards includes "computational thinking" as part of integrated STEM education and a component of scientific and engineering practices. An important outcome of the recent, "Engineering Design and Practices Roundtable: Working Together to Advance Pre K-12 Engineering Design" convened by the Museum of Science in Boston in January 2015, was recognition of the need to operationalize the definition and competencies for computational thinking across a range of populations including pre-college, researchers and curriculum developers. Experience with computational thinking abilities can positively influence STEM learning for students across all grade levels. Understanding of computational thinking integrated with STEM learning helps students build connections across disciplines.

B. Decision To Focus On Pattern Recognition

Given the literature on computational thinking (CT) and standards for college and pre-college, it is evident that CT is a complex and multi-faceted competency [2] [3] [4] [5] [6]. This raises issues with regards to the assessment of CT broadly. We need to address specific aspect of CT.

Figure 1 represents core computational thinking competencies defined in three notable reports published in recent years (Barr & Stephenson, 2011, CSTA, 2011 and

Fig. 1. Core computational thinking competencies at undergraduate and K-12 levels



Barendsen & Stoker, 2013). Figure 1 is our representation of an amalgamation of aspects of CT. In this figure, the orange circle represent CT competencies specific to computing while the green ones represent more general competencies common to STEM fields. The grey circle on the right and left sides of the larger circle represent even broader competencies applicable beyond STEM education. Pattern recognition, however, was not captured as an individual CT competency in these reports aforementioned and summarized in Figure 1. Table 1 compares the components of computational thinking to identify those that are prominent. Again in Table 1, "pattern recognition" is not a specific competency but was noted as part of other competencies within CT and used to describe several other higher level computational thinking competencies. These occurrences are noted in bold and italic emphasis. However, the "CT concepts Guide" published by Google highlights pattern recognition and pattern generalization as individual CT competencies [7]. As a result of this analysis, we considered pattern recognition as a fundamental ability within CT. Therefore, we decided to carry out a systematic review to identify articles that study learning of pattern recognition.

TABLE I. Specific Computational Thinking Competencies that require Pattern Recognition

CT Competencies	Barr & Stephenson, 2011 (US K-12)	CSTA. Computational thinking teacher resources, 2nd Edition, 2011 (US K-12)	Barendsen & Stoker, 2013 (Coding Scheme from CSTA CT categories) (US K-12)
1. Abstraction	Use procedures to encapsulate a set of often ***repeated commands (patterns)*** [a.] that perform a function; use conditionals, loops, recursion, etc.	Reducing complexity to define main idea.	
2. Automation		Having computers or machines do ***repetitive (patterns)*** or tedious tasks.	Recognizing different forms of automation. Recognizing the advantages of automation.
3. Generalization		***Identifying patterns***, similarities and connections, and exploiting those features. It is a way of quickly solving new problems based on previous solutions to problems, and building on prior experience.	
4. Data Analysis	Write a program to do basic statistical calculations on a set of data.	Making sense of data, finding patterns, and drawing conclusions.	Drawing conclusions. ***Finding patterns***. Making sense of data.

[a.] Pattern recognition as part of definition of computational thinking competencies

II. METHOD

A. Locating Articles

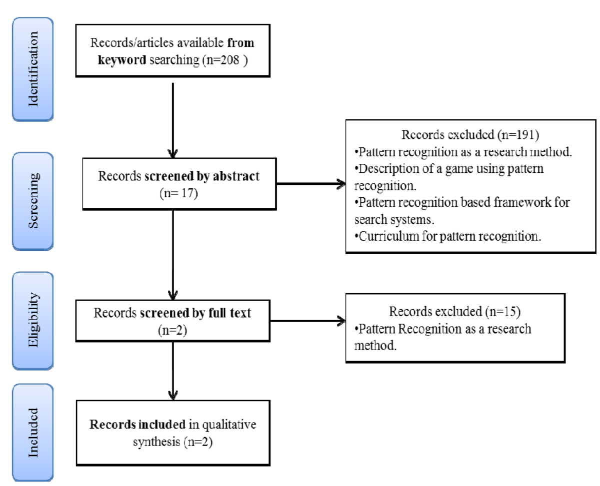
The systematic review comprised of an engineering education based research database, Engineering Village, which carries articles from two other databases, Compendex and INSPEC. We specifically focused on an essential engineering research database to examine research on learning pattern recognition. The keywords "(pattern recognition OR pattern generalization) AND education" were used in the keywords/subject, title, and abstract of papers were used to search within the journals.

B. Exclusion and Inclusion Criteria Units

The systematic review covered articles since 1977, the year Kay & Goldberg published about SmallTalk in IEEE which was a language that could be used to communicate using small computer. The search was limited to peer-reviewed journal articles published from 1977 to 2016 across all educational levels. The initial search results yielded 144 articles for Compendex and 64 articles from INSPEC. Article abstracts were first reviewed to identify relevant articles. Next, full articles were reviewed for evidence of teaching and student learning about pattern recognition.

A summary of the systematic review process is presented in Fig. 2. This search process resulted in 208 articles. Next, all abstracts were read and those that specifically discussed studies to investigate pattern recognition as a competency in STEM education and computational thinking, were considered for analysis.

Fig. 2. A flowchart of the systematic review process



The articles that were considered to be excluded described pattern recognition in four ways (i) pattern recognition as a research method; (ii) description of a game using pattern recognition; (iii) pattern recognition based framework for search systems; (iv) description of curriculum. Our systematic review yielded 17 articles. Two researchers (the author and coauthor) read these articles in full.

III. RESULTS

After a detailed review of the complete articles, two articles were identified, that discussed learning of pattern recognition as a CT competency.

Tanimoto et al., 1998 [8] is a position paper that discusses the importance of pattern recognition and computer vision in mathematics education among middle school students. Kellman, 2013 [9] is an article in the area of medical sciences that identifies pattern recognition as one of the pertinent abilities in extracting information from instructional material for medical students. This article provides an insight into how medical professionals recognize patterns in their workspace. The insights from this study can inform assessment of pattern recognition for example, how to recognize patterns across images and within games.

IV. CONCLUSIONS

A review of the definitions for CT competencies indicated pattern recognition as foundation for other higher level competencies. A systematic review described in this study based on an engineering database, however, only yielded two relevant pattern recognition-based articles. Engineering and computer science educators consider pattern recognition an important fundamental ability for student learning. Thus, our findings demonstrate a need for additional studies that measure pattern recognition in CT across a range of K-undergraduate educational levels. This will bear implications for the design of curriculum and assessment either interwoven with STEM lessons or as an independent track across undergraduate and K-12 classrooms.

As evidenced, in our analysis, pattern recognition in engineering and computer education as a component of computational thinking is new; much can be learned from a rich body of research in mathematics or gifted education. Hence, future research should focus on the review of STEM and psychology related databases (such as ERIC) and translation of this body of knowledge to inform education of computation thinking. It is possible that pattern recognition is perhaps difficult to pull out as a discrete competency in the context of computing and hence our results did not yield a large number of articles. However, our next steps involve identification and screening of articles for the remaining computational thinking competencies (Fig. 1). We also plan to find articles from other psychology and STEM based databases for computational thinking competencies.

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