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Enhancing Teaching Computational Thinking: a Systematic Mapping of Pedagogical Patterns

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Abstract

Efforts to enhance understanding Computational thinking (CT) are curtailed by: (i) problem solving complexity linked to implementing a new subject; and (ii) teaching CT for problem solving is a new field. Unfortunately, the only support available are pedagogic theories and anecdotal explaining other's practice. Implementing these theories can be challenging, hence continuous research on realistic methods of sharing successful and commendable practice amongst educators, necessitating this study. Systematic Mapping (SM) was used with the following steps: research questions formulation; identifying keywords; identifying source databases; defining inclusion and exclusion criteria; constructing the search string; conduct the search; data extraction; and presentation of results. 22 studies were selected with the majority being solution proposal research. The identified pedagogical patterns were mapped to the 5Es of Framework of Action. Several patterns for solving assessment related problems were also identified hence the inclusion of the 6th E (Evaluation).

Keywords: pedagogical patterns, systematic mapping, computational thinking, teaching computational thinking, framework of action

Introduction

Recently, researchers have progressively reviewed matters related to teaching and learning (Fioravanti, Barbosa, 2016), with computational learning applications, playing a vital role in teaching and training activities, displaying growing significance (Svetlana, Yoon, 2009). This includes teaching and learning CT. Developing CT education necessitates teachers to be methodically prepared as regards to designing CT learning activities, teaching and assessing CT, and teaching CT concepts using technologies (Angeli, Giannakos, 2019). Although significant attempts have been made in improving the conceptualization of CT, teaching CT for problem solving is a new domain for most teachers coupled with complexity of problem solving resulting from executing new subject matter (Cooper, Gunckel, 2019). There are also challenges resulting from existing and emerging learning designs as a result of new ideas augmented by utilization of new technologies (Laurillard, Derntl, 2014).

Despite the challenges, teachers are required to equip themselves with new subject knowledge (Brown et al., 2013; Sentance et al., 2013; Thompson, Bell, 2013), and embrace new suitable subject delivery pedagogies more so, those associated with algorithms, programming and development of CT (Sentance, Csizmadia, 2017). Unfortunately the only support available are the pedagogical theories and anecdotal explanations of other's practice (Laurillard, Derntl, 2014). The implementation of these theories and research can be challenging, hence the continuous research on realistic methods of sharing successful and commendable practice amongst educators (Philip, 2018).

This paper investigates the existing research on pedagogical patterns, with the aim of establishing their suitability in enhancing teaching CT. To achieve our aim, a systematic mapping was performed by analysing scientific papers from various sources. The results are relevant as more studies on improving the conceptualisation of CT are still underway. CT teachers just like other teachers require well documented pedagogical practices that could help enhance their teaching.

The subject matter of the study. Related Studies

Teaching CT has conventionally been perceived as predominantly a constructionism undertaking (Bers et al., 2014; Buss, Gamboa, 2017). Constructionism posits that by constructing significant projects in a community of learners and carefully reflecting on the process, deep learning can take place among the learners (Bers et al., 2014). Thus learners, through technology are accorded autonomy to discover their own interests (Bers, 2008) while exploring domain-specific content learning and applying metacognitive, problem-solving, and reasoning skills (Bers et al., 2014; Papert, 1980). Constructionism is based on the view that the most effective learning experiences stem from four core activities: designing, personalizing (Bruckman, 2006; Papert, 1980), sharing (Papert, 1980), and reflecting (Kolodner et al., 2003; Papert, 1980).

As teachers embrace the teaching of CT, novice teachers find it hard and time consuming matching existing pedagogical practices to existing pedagogical theories while depending on their insight or pedagogies observed when students (Maher et al., 2020). Teachers require strategies and supporting documentation that would enhance the teaching of CT and this include pedagogical patterns. This study explored the existing pedagogical patterns to identify the relevant pedagogical patterns and map them to the 5Es (**E**xplore, **E**nvisage, **E**xplain, **E**xchange and bridg**E**) of Framework of Action. The *Framework of Action* by (Benton et al., 2016, 2017), comprising five unordered components dubbed 5Es that present a guide for establishing the right levels of intervention with the desire to design a constructionist approach to learning (Benton et al., 2017). With the 5Es giving the intervention points, teachers need a guide on how to implement the interventions hence the need for relevant pedagogical patterns.

Research methodologies and tools. Systematic Mapping

Studies involving pedagogical pattern, resulting from architectural patterns (Alexander et al., 1977; Alexander, 1979), have evolved from the building of patterns and pattern languages (Bergin et al., 2002), to refined studies that looked at how the existing patterns can be mapped to the problems that they can solve (Köppe, 2015; Fioravanti, Barbosa, 2016, 2018). Teaching CT for problem solving has elicited several challenges, provoking the need for accessible, easy to use, and adaptable contextualised models and representations (Bennett et al., 2007; Bower, 2017; Goodyear, Retalis, 2010) such as pedagogical patterns. The main contribution of this study is to identify the relevant pedagogical patterns and systematically map them to the 5Es to facilitate the implementation of interventions required to develop CT among learners.

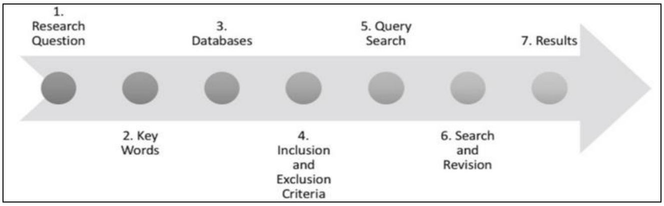


Figure 1. The Systematic Mapping Process (Ramirez et al., 2017)

The following steps (Figure 1) were performed in the systematic mapping (SM) process: (i) three research questions were formulated, (ii) identifying keywords for the searches in English (iii) the source databases defined, (iv) the paper inclusion and exclusion criteria and time range defined, (v) defining the search string, (vi) conduct the search, (vii) Data extraction, (viii) presentation of results.

Analysis of research results

1. *Defining Research Questions*

In this study, the aim of the SM was to conduct a review on the existing pedagogical patterns with emphasis on: (i) establishing the patterns that can be used to teach CT and (ii) map them to the learning activities based on the problems they can solve. The following questions were raised to guide the study:

Q1: What existing pedagogical patterns can be deployed in teaching CT?

Q2: What problems do the identified pedagogical patterns aim at solving or mitigating while teaching CT?

Q3: Where can the pedagogical patterns be applied to enhance teaching CT?

2. *Identifying Keywords for the Search*

The following keywords in English were used to obtain better results of the searches and enable a more comprehensive review in the databases: pedagogical pattern(s), educational pattern(s), teaching pattern(s) and learning pattern(s).

3. *The Source Databases*

It is recommended searching several electronic sources (Brereton et al., 2007). The search was conducted in the following databases: Google Scholar, ACM, Scopus, Springer Link, Web of Science and ScienceDirect. The databases are internationally recognised in engineering, computer science and education research (Ramirez et al., 2017). A generic search string was deployed realising 6,291 hits as distributed in Table 1, out of which 2956 were identified as duplicates and excluded. The remaining 3,335 articles were explored further in the screening step.

Table 1. Articles per Database Searched

Database	**URL**	**Acronym**	**Total Studies**
Google Scholar	<scholar.google.com>	GS	2,304
ACM Digital library	<dl.acm.org>	ACM	289
Web of Science	<webofknowledge.com>	WoS	554
Springer	<link.springer.com>	Springer	1,514
SCOPUS	<scopus.com>	SCOPUS	712
Science direct	<sciencedirect.com>	ScienceDirect	918
Total			**6,291**

4. *Screening the Articles for Inclusion and Exclusion*

To avoid missing out on important studies the time range of the studies was undefined. Inclusion and exclusion criteria were applied to establish the studies that possess the potential of answering the research questions.

Inclusion: Primary studies that: (i) contain at least one full pedagogical pattern that can be used in teaching CT; (ii) papers published in journal, conferences, books, book chapters; (iii) papers written in English; and (iv) papers found in the databases listed and can be downloaded.

Exclusion: Studies that: (i) cannot be downloaded; (ii) not written in English; and (iii) Gray literature.

Out of the 3,335 studies evaluated, 25 were selected for the next step. This was arrived at by reading the paper to establish if it can help answer the research questions.

5. *Defining the Search String*

The search does not involve all the existing pedagogical patterns, but only those relevant to the teaching of CT. Considering that there are no pedagogical patterns for teaching CT in particular, search string shown in Table 2 was formed using generic but relevant terms.

Table 2. Generic Search String

("pedagogical pattern" OR "pedagogical patterns" OR "teaching pattern" OR "teaching patterns" OR "educational pattern" OR "educational patterns")

6. *Search Process*

The abstracts were read in search for the keywords and concepts that reflect the contributions of the paper to identify the relevant articles. The classification was done using two main facets:

Pattern category: used to group the patterns based on their application towards the development and enhancement of CT. The patterns were organised according to the 5Es of *Framework of Action* (Benton et al., 2016, 2017) summarised in Table 3, that acted as a guide in establishing the right levels of intervention coupled with the desire to design a constructionist approach to learning (Benton et al., 2017).

Table 3. 5Es of Framework of Action

Component	Description
Explore	Learners requirechances to investigate concepts by attempting issues on their own and correcting errors (Benton et al., 2016, 2017).
Envisage	Learners should be inspired to project the results before creating the projects and then reflect on the real result.
Explain	Teacher as well as peer facilitated opportunities should be availed to the learners using reflective questioning (Benton et al., 2017).
Exchange	Inclusion of significant possibilities for sharing and building on others' ideas (Benton et al., 2017).
BridgE:	Ideas are perceived as influential partly due to their link to other fields for example mathematics (Papert, 1980).

Research type: reflects the research approach employed in the articles. An existing classification of research approaches by Wieringa et al. (2006), summarised in Table 4 was used (Wieringa et al., 2006).

Table 4. Research Type Facet

Category	Description
Validation Research	Investigate novel techniques for example experiments.
Evaluation Research	Evaluation of already implemented techniques.
Solution Proposal	A proposed problem solution that can be either novel or a significant extension of an existing technique.
Philosophical Papers	Draw a new way of viewing existing things by organizing the study in the form of a taxonomy or conceptual framework.
Opinion Papers	Express personal opinion and do not rely on related work and research methodologies.
Experience Papers	Explain what and how something has been accomplished in practice, giving the author's own experience.

7. *Data Extraction and Mapping process*

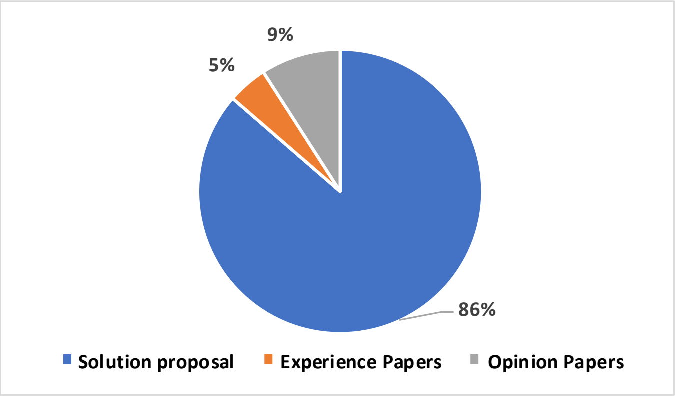
Data was extracted from the studies using a data extraction template in Table 5 and the results summarised to answer the research questions.

Table 5. Data Extraction Template

Field Name	Description	RQ to be Answered
Research ID	Comprising letter 'R' and an integer	
Research Title	Title of the research	
Author(s) & Pub Year	Name of the author(s) & year of publication	
Research Type	Research classification (Table 3)	
Pattern ID	Comprising letter 'P' and an integer	
Pattern Name	Name of the pattern	RQ1
Application Problem	Problem where the pattern is applied	RQ2
Pattern Category	Pattern application area	RQ3

8. *Results of the Systematic Mapping*

In this step, the summary of the selected articles is presented with the articles categorised using the research type as shown in Graph 1.



Graph 1. Distribution of Selected Studies based on Research type

Solution proposal studies formed most of the selected studies (84%), with opinion and experience papers constituting 12% and 4% respectively. Validation research, evaluation research or philosophical papers were missing among the selected studies. This is evident that even though pedagogical patterns for various solutions have been proposed, their validation and evaluation is still lacking. The selected studies and their information are initially presented in summary form as shown in Table 6.

The patterns selected were based on the 5Es of *Framework of Action* (Benton et al., 2016, 2017) summarised in Table 3, guided by the core learning activities: designing and creating, personalisation, sharing and reflecting (Brennan, 2015).

Table 6. Selected Articles

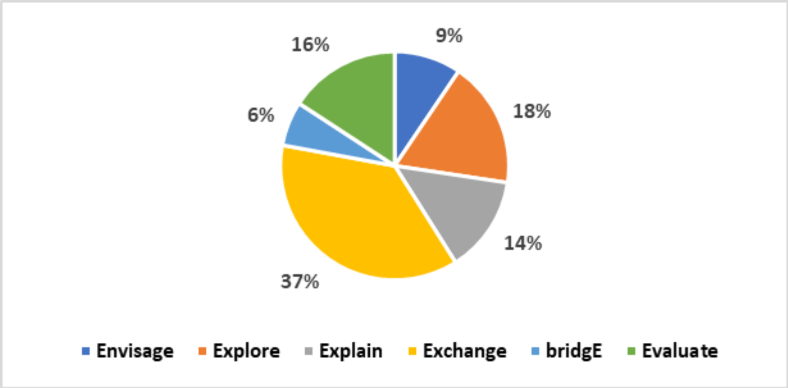
ID	Title of the Study	Author(s) & Year
R01	Pedagogical Patterns for Creative Learning	Iba et al., 2011
R02	Learning Patterns III: A Pattern Language for Creative Learning	Iba, Sakamoto, 2011
R03	Learning Patterns: A Pattern Language for Creative Learners II	Iba, Miyake, 2010
R04	Educational Patterns for Generative Participants: Designing for Creative Learning	Shibuya et al., 2013
R05	Educational Design Patterns for Student-centred Assessments	Köppe et al., 2020
R06	Lecture Design Patterns: Improving Interactivity	Köppe, Schalken--Pinkster, 2013
R07	Assessment-Driven Course Design – Fair Play Patterns	Bergin et al., 2015
R08	Flipped Classroom Patterns – Designing Valuable In-Class Meetings	Köppe et al., 2015
R09	Patterns for Gaining Different Perspectives	Bergin et al., 2001
R10	Continuous Feedback Pedagogical Patterns	Larson et al., 2008
R11	Learning Patterns for Group Assignments – Part 1	Köppe, 2012
R12	Learning Patterns for Group Assignments – Part 2	Cortie et al., 2013
R13	Improving Student Group Work with Collaboration Patterns: A Case Study	Köppe, Eekelen et al., 2015
R14	Patterns of Active Learning	Eckstein et al., 2002
R15	Applying and Developing Patterns in Teaching	Bennedsen, Eriksen, 2003
R16	Pedagogical Patterns Successes in Teaching Object Technology A Workshop from OOPSLA '96	Sharp et al., 1996
R17	Active Learning and Feedback Patterns Version 4	Bergin, 2006
R18	Interaction Design Patterns for Classroom Environments	Breuer et al., 2007
R19	Patterns for the creation of e-learning content and activities in a university setting	Holden et al., 2010
R20	Design and Communication Patterns Observed in an eLearning Design Team: A Case-Study	Rapanta et al., 2010
R21	A Pedagogical Pattern Language for Mobile Learning Applications	Fioravanti, Barbosa, 2017
R22	Guess my X and other techno-pedagogical patterns: Toward a language of patterns for teaching and learning mathematics	Mor, 2010

A total of 73 patterns were extracted and summarised as shown in the excerpt in Table 7. The table shows the pattern ID, name and problem the pattern is supposed to solve. The patterns were further categorized according to the teacher interventions guided by the 5Es of Framework of Action as shown in *Graph 2*. Exchanges that cover collaboration, group work and even sharing have the highest number of patterns with 37%. This shows how much collaboration has been prominent in learner-centred learning. Evaluation, which was not one of the 5Es also had higher % hence forming the 6th E in the study.

Table 7. Excerpt of Patterns and the Application Problems

Pattern ID	Pattern name	Problem
1	***2***	***3***
P01	Discovery-Driven Expanding	Suddenly introducing collaborative learning (learner-centred learning) creates difficult for learners to perform and learn from their experience effectively.

1	*2*	*3*
P02	Generative Participant	Communication for the collaboration doesn't always go smoothly and often stops and sometimes falls into the situation where a very few members control and others follow it
P14	Student Miners (Collaborative Knowledge Construction)	Just presenting a new concept makes it hard for students to relate this new knowledge to their existing knowledge and keeps them in an undesired passive role.
P15	Question Parking Space	Handling learners' questions that do not directly relate to the content or require a longer or very specific answer.
P16	Collaborative Summary	It keeps learners passive if you just present the list of content covered to the students and run through all the bullets.
P23	Every Student Solution Counts	Students may feel that their work is not considered relevant and stop handing it in.
P25	Explore For Yourself	You want to give your learners the ability to learn in the future and to communicate their wisdom, but students are often afraid of taking responsibility for their own learning.
P30	Think...Pair...Share	Students' focus is not on the lesson.
P37	Share Expectations	Students might have different expectations of the results and the way of working on the assignment. This often leads to conflicts or an inefficient way of working.
P41	Mediate the Dispute	There is a dispute between group members, which has a negative impact on the motivation and the participation. There might be negative consequences on the project results.
P42	Keep Motivated	During the execution of a group assignment, insufficient participation, bad quality deliverables or simply not getting satisfaction from the given tasks can be the result of decreased motivation.
P44	Regularly Check Requirements Fulfilment	A group assignment is given to a group of students. The project consists of single or multiple deliverables and the quality requirements for both intermediate and final goals are determined, either by the teacher or the students. You are at the beginning, middle or final phase of the project.
P49	Invisible Teacher	Usually, the teacher is the central point of a training environment. Often the students only trust the teacher and (maybe) themselves, However, in the work environment the teacher will not be around.
P50	Study Groups	Your best students may often be bored, because they have finished a task quickly while the poorest struggle constantly.
P52	Real World Experience	A lot of concepts are too abstract for students to conceive their value and learners often doubt the viability of these concepts
P55	Nobody is Perfect	Learners expect only one right solution to a problem from the instructor. However, there is no single answer, but many equally correct answers.
P56	Explore-Present-Interact--Critique (EPIC)	Allows learners to learn new material efficiently and share the knowledge with peers by forcing them into being the teacher for themselves.
P58	Play, Reflect, Jump	How to kick-start the learning design process, create a shared vision for the aims of the course and ensure the overall vision for the course is reflected in its detailed learning design plan.
P73	Soft scaffolding	Providing direction and support while maintaining the learners' freedom, autonomy and sense of self as well as the teachers' flexibility to adapt.



Graph 2. Pattern Categorised According to the Application Areas

Conclusions and Way Forward

This study presented a mapping of pedagogical patterns to be deployed in the teaching of CT. The motivation towards pedagogical patterns approach is necessitated by the need for sharing knowledge and good practices between research literature and the real world, for facilitation and communication purposes between stakeholders. A systematic mapping methodology was deployed with the aim of conducting an impartial assessment of the literature. It is worth noting that the study concentrated in establishing the pedagogical patterns that can be used by teachers while executing the interventions at the various intervention points guided by the 5Es of the Framework of Action (Envisage, Explore, Explain, Exchange and bridgE) in learner-centred learning. Assessment patterns contributed to 16% of the patterns identified hence necessitating the inclusion of a new component – Evaluation) forming the 6th E. This study is part of the study to develop a comprehensive and flexible framework for developing and enhancing CT among learners in different learning levels and different learning contexts.

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