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DOI:
10.1145/3341525.3394006

Published: 15/06/2020

Document Version
Publisher's PDF, also known as Version of record

Please cite the original version:
Zavgorodniaia, A. (2020). *Efficient Instructional Design of Programming Examples*. 581-582. Paper presented at Annual Conference on Innovation and Technology in Computer Science Education, Trondheim, Norway. https://doi.org/10.1145/3341525.3394006

Efficient Instructional Design of Programming Examples

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ABSTRACT

This research is dedicated to the theory which underlies programming teaching through the worked examples. Today Computing Education Research (CER) has a lack of agreement on the efficiency of different methodologies applied in programming teaching. I investigate the influence of the following practical factors on learning: modality effect, segmentation effect, visualization, and self-explanation.

CCS CONCEPTS

• **Applied computing → Computer-assisted instruction**; *Distance learning*.

KEYWORDS

cognitive load; programming teaching; worked examples

ACM Reference Format:
Albina Zavgorodniaia. 2020. Efficient Instructional Design of Programming Examples. In *2020 ACM Conference on Innovation and Technology in Computer Science Education (ITiCSE'20), June 15–19, 2020, Trondheim, Norway*. ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3341525.3394006

1 CONTEXT AND MOTIVATION

Nowadays we can find less and fewer people who would not have heard about programming. More and more become eager to learn it. Programming skill requirements seem to conquer the job market. What can we, scientists, do helpful in this situation? My personal answer is - to find a better way of teaching programming. This is one of the major topics in Computing Education Research (CER).

CER is a field emerged in the late '60s, which seeks to create new efficient methodologies to be applied in computing teaching. Its mission is to make computing more accessible and easier to comprehend. However, since CER is a young field, it still lacks own well-structured consistent theoretical background and faces many challenges. The motivation for my research is a conviction that educational theory is highly important, and programming is a specific domain which requires to have its own methodology indeed.

2 BACKGROUND

Cognitive science is usually referred to as an interdisciplinary study of mind and its processes. Its knowledge has been influencing and guiding many disciplines, CER inclusive [11]. The most prominent topic in cognitive science is a *cognitive load theory* (CLT). It reflects our 'cognitive architecture' or the way of information processing [12]. Assumptions, on which the CLT is built, include: that memory can be divided into a *working memory* and a *long-term memory*; information is stored in schemas format in long-term memory; intentional processing of new information causes *cognitive load* on working memory which can affect the quality of learning [1–3]. The cognitive load is commonly considered to be presented by three types: intrinsic, extraneous, and germane.

Reducing cognitive load is an essential task in all the teaching practices. Worked examples are the most wide-spread method of minimizing cognitive load. The analogical reasoning theory states that providing worked examples can enable learners to approach new problems using analogy [6]. Sweller [13] argues that learning via worked examples is more efficient than learning via problem-solving due to the nature of human cognitive architecture. As the method found strong support in programming teaching and proved to be useful (for example, [9]), this research will have worked programming examples as a base.

Teachers use various materials and ways of presenting them during the programming classes such as lectures, practical assignments, e-books and interactive learning resources, and students utilize different sources of information. Educational psychology indicates some factors which affect the perception of material presentation and cognitive load. Among those factors are modality [7], segmentation [8, 10], visualization [14] and self-explanation [4]. This project will investigate the influence of each of the factors on learning programming through worked examples.

3 PROBLEM STATEMENT

Currently, the research on teaching programming through the worked examples is rather scattered and somewhat inconsistent. This research project seeks to find answers on the questions listed below and to develop a set of rules for creating teaching materials.

The research questions are as follows:

RQ 1: Is dual modality superior to a simple text in terms of programming learning and if it is under what conditions?

RQ 2: Is presenting segmented code explanations superior to continuous explanations in terms of learning from worked examples?

RQ 3: Does binding program visualization with the code tracing facilitate learning programming and could modality and segmentation effects influence it?

RQ 4: How can we reach a balance between giving students instructions and prompting them to construct knowledge through the active learning tasks?

ITiCSE '20, June 15–19, 2020, Trondheim, Norway

ACM ISBN 978-1-4503-6874-2/20/06.
https://doi.org/10.1145/3341525.3394006

4 RESEARCH GOALS

The main goal of this research project is to investigate how and under what conditions people learn programming through the worked examples best. As stated above, the central learning effects for the revision are modality, segmentation, visualization and self-explanation. For the sake of yielding consistent, grounded theoretical conclusions, the research will include replications of some existing studies. Even in the straight-forward experiments, secondary independent variables can be present, causing a significant impact on the learning process (for example, voice intonation in the audio explanations, the commentator's gender, formatting of the materials). Therefore, for making valid claims, I plan to perform different variations of the experiments. As an outcome, I will develop a set of logically tied recommendations for the teaching materials design process.

5 RESEARCH METHODS

The research project will utilize a quantitative method, more precisely - experiments. Each of the experiments will provide participants with a programming learning material, based on worked examples, along with expert instructions. After each learning session, the participants will complete assessment tasks, designed in such a way to evaluate the efficiency of the transfer process (meaning transferring the declarative knowledge to solving the novice problems). Since the research goal is to improve teaching interventions both in classroom teaching and online courses, the experimental settings will correspond. I acknowledge that laboratory experiments in controlled conditions can be far from reality, therefore, the aim is to find treatments which would have a significant positive impact despite the possible distracting factors which *may* and often *do* occur in real life when the learning process is happening. Thus, the experiments are going to be held at Aalto University on a course basis and in the form of online-teaching on the Amazon Mechanical Turk platform (with a possible extension to university online-courses). This will allow gaining insight from a wide demographic circle, thus, possibly will lead to the development of more general and, therefore, more broadly applicable recommendations.

Taking into consideration the project's cognitive science grounds, which always imply multiple factors influencing perception and, therefore, learning, I can not omit a qualitative research approach. It will also take place in the studies. Naturally, each experiment will include a survey inquiring about learning and social background, learning motivation, etc. However, apart from that, computing education workshops are also planned to be held at Aalto University to support hypotheses formation and maintain the connection to a teacher's/student's reality. The purpose of those will be to reveal actual struggles of teachers preparing the teaching materials, their observations and needs, as well as students' learning approaches, preferences and opinions on current teaching methods applied in their courses. As Hargreaves [5] pointed, the scientific questions in education research must emerge from the *'science consumers'* or practitioners.

6 EXPECTED CONTRIBUTIONS

The purpose of this research project is to contribute to the theoretical body of Computing Education Research, specifically, the topic of programming teaching. The experiments will be built and performed in the way, to support or contravene previous studies and complement each other in terms of the research project, in this way building on the existing knowledge of the domain. I expect to create a scalable theoretical framework for programming teachers which will describe the most advantageous ways of designing teaching materials based on worked programs, either for classroom teaching or online courses. The methodologies are expected to be utilised at Aalto University by teachers from the Department of Computer Science in both settings as well. Through international connections and collaboration, I hope to spread the knowledge to other educational institutions.

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