WIP: Object-Oriented Design Education: A Systematic Mapping Study

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***Abstract*—This WIP paper performs a systematic mapping study to investigate the evolution and trends in object-oriented design education (OOD), a critical aspect in software engineering curriculum. Based on 228 publications, the study illuminates significant pedagogical shifts in object-oriented design (OOD), distinguishing it from object-oriented programming (OOP). It also identified areas lacking in-depth research coverage. The research questions guiding this investigation include: 1) Which publication channels predominantly disseminate OODE research? 2) What teaching approaches are most reported in OODE research, and how have these approaches evolved over time? Our findings indicate a trend towards interactive and student-centered teaching methods yet underscore a pressing need for empirical studies to validate these educational strategies. This study aims to provide actionable insights for educators and curriculum developers to refine OOD teaching practices, aligning them more closely with evolving industry standards. Our future work will focus on in-depth analysis of our primary studies to gain insights on the impact of emerging technologies such as AI and VR on learning outcomes in OOD. We also plan to develop guidelines for effective integration of OOD in software engineering curriculum.**

Keywords— Software design, Software design learning, Systematic study.

I. INTRODUCTION

In the evolving landscape of software development, the principles of object-oriented design (OOD) and object-oriented programming (OOP) play critical roles, yet they serve distinct purposes and necessitate different educational approaches. While OOP focuses on the implementation aspects of programming using objects and classes within various programming languages, OOD involves a broader conceptualization, emphasizing the architecture and interaction of objects before coding begins. This higher-level thinking is crucial for creating robust and scalable software systems, making it an essential skill for developers. Despite its importance, the teaching of OOD is often conflated with or overshadowed by the more straightforward techniques of OOP. This confusion can lead to educational programs that inadequately prepare students for the complexities of real-world software design. Recognizing this educational gap, our study aims to dissect the current methodologies used in teaching OOD, to distinguish them from those used in OOP, and to identify ways to enhance the teaching of these foundational design principles.

This paper sets out to bridge the gap between theoretical knowledge of OOD and its practical application in educational settings. By conducting a systematic mapping study of 228 publications spanning over three decades, we seek to capture a comprehensive snapshot of how OOD is currently taught across various educational platforms and how these methods align with the demands of modern Software Engineering Design.

Research Questions:

RQ-1: Which publication channels are the main targets for Object-Oriented Design Education (OODE) research?

RQ-2: What are the approaches that were reported in OODE research and how has the frequency of those approaches changed overtime?

Employing a systematic mapping study, this research critically reviews 228 publications spanning over three decades. This methodology allows for a thorough categorization and analysis of the pedagogical approaches and educational venues influential in shaping OODE. The findings are expected to reveal a variety of teaching methodologies, shedding light on their effectiveness and areas needing enhancement. This could lead to the development of more refined and targeted educational practices that are directly aligned with the evolving requirements of the software industry.

The remainder of this work-in-progress paper is structured as follows: Section II presents a detailed literature review,

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exploring historical and current perspectives on OOD education. Section III describes the methodology employed in this study. Section IV discusses the findings and their implications for educators and practitioners. Finally, Section V outlines potential future research directions and concludes the paper.

II. Related Literature

The landscape of software design has experienced significant transformations with the maturation of the OOD paradigm, a shift from traditional procedural programming to a framework where software systems are seen as collections of interacting objects, encapsulating both data and behaviors. This profound shift has not only revolutionized SWD practices but has also necessitated a reevaluation of educational strategies within this domain, highlighting the need for an educational approach that aligns with the complexities of modern software design. The evolution of software design thinking has been significantly influenced by key figures such as Jack W. Reeves, Robert Glass, and C. Hu, each contributing foundational insights into the cognitive processes involved in software design. Reeves [1], in his seminal work, posited that software design, in essence, constitutes the core documentation of engineering design—primarily the source code itself. Glass [2] extended this viewpoint by describing software design as a rapid, cognitive simulation process that iteratively proposes and tests solutions. Further refining this perspective, Hu [3] described software design as a systematic and intelligent process tailored to meet specific user needs within defined constraints, emphasizing a strategic rather than merely technical approach to SWD. Despite the academic insights provided by these pioneers, a notable disconnect persists between theoretical frameworks and practical methodologies applied in education. This gap is vividly illustrated in the teaching of OOD, where rapid technological advancements and evolving industry demands continue to outpace educational reforms.

The critical challenge lies in educating not just about the technical aspects of OOD but also fostering the capability to abstractly think and solve complex problems through design. A significant portion of research in OOD education has been highlighted at major forums such as the Frontiers in Education conference. Börstler [4] and others have noted the ongoing debate on how best to teach this paradigm, reflecting the need for educational methods that not only teach the programming aspects but also the underlying design principles.

Recent systematic mapping studies and literature reviews, such as those conducted by Medeiros Ramalho & Falcão [5] highlight the distinction between teaching introductory structured programming and imparting a deeper understanding of designing under the object-oriented paradigm. These studies underscore the need for a clear understanding of how OOD thinking, and design are taught and emphasize the necessity for curricula that reflect the deep conceptual nature of OOD rather than merely focusing on programming techniques.

This body of literature forms the foundation for this study's exploration of OOD education, providing a clear context for assessing the current state of the art and identifying potential areas for innovation and improvement in teaching methodologies.

III. Systematic Mapping Study

In the domain of academic research, a Systematic Mapping Study (SMS) serves as a specialized form of secondary research aimed at offering a comprehensive overview of a particular research domain by categorizing and quantifying research contributions, as initially defined by Petersen, Vakkalanka, & Kuzniarz [6]. Its primary objective is to address broad research inquiries, which help discern the current situation within the respective research area. Conversely, a Systematic Literature Review, also a form of secondary research, is designed to tackle research queries demanding an in-depth examination of the subject matter. In the context of our study, we have opted for a SMS , as our intent is to explore overarching questions that pertain to the overall landscape of the research topic rather than delving into specific facets of it. Our execution adheres to the procedural guidelines for conducting secondary studies put forth by Kitchenham et al. [7]. According to these scholars, the secondary review process can be distilled into three crucial phases: planning, execution, and reporting of the review. In the forthcoming sections, we will provide a detailed account of how each of these three phases was applied to our review. For visual clarity, we have encapsulated the entire review process in Figure 1, with corresponding sections outlined within this paper.

A. Review Planning

The details of the review process are outlined in Fig. 1.

a) Identification of Need: Several papers have been published about teaching and learning OOD to answer questions such as the following by Northrop, [6].

• How much of the paradigm language, analysis, design, and management ought to be addressed?
• At what level in an undergraduate program are object-oriented techniques appropriate?
• How is the object-oriented approach effectively taught?
• How to begin teaching programming: With structured or object-oriented methods?

Annually, a significant body of research is disseminated, each targeting various facets of these queries. Considering the extensive proliferation of papers and the numerous questions embedded within contemporary academic discourse, it becomes imperative to delineate the state of the art in OODE.

b) Research question: The research questions defined for our study about OODE are presented in Table 1.

c) Review Protocol: Within this segment, we elucidate the review protocol employed in our research. We provide a comprehensive account of our search strategy and the methodology for data extraction.

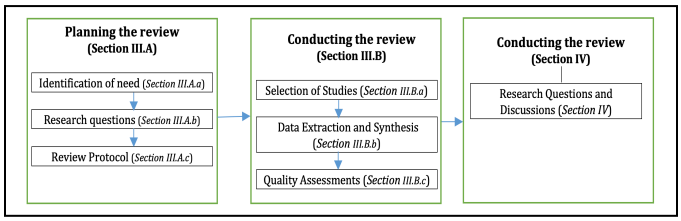

Fig 1. The SMS process, indicating paper´s sections where it is explained.

TABLE I. RESEARCH QUESTIONS

Id.	*Research Question*	*Motivation*
RQ1	Which publication channels are the main targets for OODE research?	To identify where OODE research can be found as well as the good targets for publication of future studies.
RQ2	What are the approaches that were reported in OODE research?	To identify the publication trends over time of OODE research.

TABLE II. CRITERIA OF INCLUSION / INCLUSION

Id.	*Criteria*	*Type*
I1	Studies proposing approaching, syllabi, contents, and techniques for object oriented design education.	Inclusion
I2	Studies proposing didactic techniques, tools, examples, and assignments for object oriented design education.	Inclusion
I3	Publications from journals, events, and newsletters in the field of Computer Science.	Inclusion
E1	Articles focused on object-oriented programming education.	Exclusion

Search design: Our research starts by establishing well-defined search parameters, considering the temporal boundaries, electronic databases, and the chosen search methodology. Defining the scope is of paramount importance as it ensures alignment with the objectives of our review and underscores the pertinence of prospective studies.

Period: Our study aims to cover the entire history of publications on Object-Oriented Design Education (OODE). We chose the timeframe of 1988 to 2021 after comprehensive database searches revealed the first publication in 1988. The data collection and analysis began before sufficient representative data for 2022 and 2023 were available, making it infeasible to include these years. We acknowledge the significant changes in teaching and learning during the COVID-19 pandemic and plan to address this aspect in future studies to update our findings.

Electronic databases: For our research review, we designated four primary electronic databases as our primary sources. These include IEEE's IEEE Xplore (http://ieeexplore.ieee.org/), The ACM Digital Library (http://dl.acm.org/), Springer Link (https://link.springer.com/) and Wiley Online Library (https://onlinelibrary.wiley.com/). These databases serve as reliable repositories for events, such as conferences, workshops, as well as journal papers.

Search strategy: We used automated searches in electronic databases to find papers relevant to our review. Later in the process, we also did a manual search, especially during a step called snowballing. Manual searches accounted for about 22% of the total, with automated methods being our main way of finding studies. Our main search term was "*object-oriented design (learning or teaching).*" Based on this, we made a few other search terms and used them too. In total, we did four searches to get as many relevant papers as possible.

Data extraction and synthesis: We analyzed count data, which only takes positive whole numbers. We counted specific variables from the studies to answer our research questions. Section III.B.c explains how we extracted this data and the variables we looked at.

B. Conducting the Review

To facilitate searches within the selected electronic databases, we have established and documented both the inclusion and exclusion criteria, along with the specific search terms employed during the study selection process.

Inclusion / Exclusion Criteria: Table II displays the inclusion and exclusion criteria utilized during the process of selecting the studies.

Search Execution: The search strings "(object-oriented design) AND (teaching OR learning)" were used to perform the first search, This search was made just in abstracts and document titles, However, this search term yielded a limited number of papers. We observed that documents pertaining to the teaching and learning of OOD often don't use the complete term explicitly. The concept of "design" that we wish to find, is referred to by many authors as "modeling" or even as "thinking". it was also noted that the word education should be included at the end of the research string.

Selection of studies: Tables III, IV, and V present a comprehensive breakdown of the searches conducted within each electronic database. These tables include information about the individual databases, the total count of studies retrieved, the number of studies selected, and any distinct adjustments made for each database.

TABLE III. FIRST SEARCH

Database	*Retrieved*	*Selected*	*Refinements*
ACM Digital Library	103	64	No refinement
IEEEXplore	65	26	No refinements
Springer Link	34	1	Selected disciplines in search: Computer Science
Wiley Online Services	11	2	No refinements

TABLE IV. SECOND SEARCH

Database	*Retrieved*	*Selected*	*Retrieved After Refinements*
ACM Digital Library	2,542	Search in abstract in proceedings and journals	141
IEEEXplore	1,509	Search in abstract in proceedings and journals	85
Springer Link	4,643	Selected disciplines in search: Computer Science.	190
Wiley Online Services	900	Search in the abstract in proceedings, book chapters, and journals	24

TABLE V. THIRD SEARCH (SNOWBAULLING)

Database	*Selected Publications*
ACM Digital Library	26
IEEEXplore	15
Springer Link	4
Wiley Online Services	4
Total	49

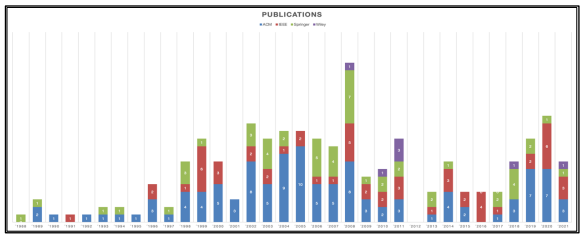

Fig 2. Distribution of primary studies according to the publication type.

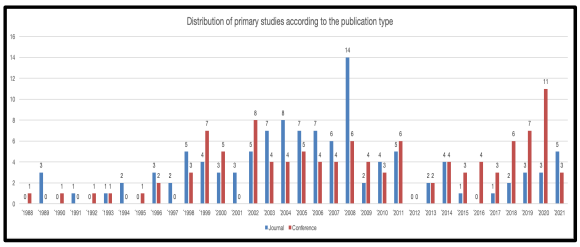

Fig 3. Distribution of primary studies according to the editorial source.

All tables align with the review's designated time frame, and the studies adhered to the criteria outlined in Table II . From our four searches, we selected 228 studies. These are spread across 31 journals and 64 events. Figures 2 and 3 show how the papers are distributed by publication type and where they were published. Table VI lists the journals that have a minimum of three chosen papers, while Table VII presents the events with at least three selected papers.

Data Extraction and Synthesis: In this section, we provide an in-depth account of the data elements extracted from the selected studies, which play a crucial role in addressing our research inquiries. Table VIII serves as a representation of these data elements; alongside the respective research questions they contribute to answering.

IV. Results

The following is a breakdown of the 228 selected primary studies that allow us to answer each one of the defined research questions.

RQ1 - WHICH PUBLICATION CHANNELS ARE THE MAIN TARGETS FOR OODE RESEARCH?

This section presents the chronological distribution of the primary studies and the type of channel in which it was published according to various criteria.

Figure 2 presents the primary studies chronologically, organizes them by type of publication, and shows the number of studies published per year. The results indicate that 50% (114/228) of the primary studies were published in conferences, while the other 50% were published in journals. It is observed that during the first ten years (1988-1997) of the analyzed period, both the number of studies published in journals and those published in conferences remained low (0-3 per year). During the following twelve years (1998-2011) it is observed that the number of studies published in conferences grows a little (3-8 per year) except for 2017 in which none was recorded.

In this same period, the number of studies published in journals grew significantly, reaching the maximum (14) over the years.

TABLE VI. Journals

Database	***Journal***	***Selected publications***
ACM	Journal of Computing Sciences in Colleges	18
ACM	ACM SIGCSE Bulletin	18
Wiley	Computer Applications in Engineering Education	6
Springer	Education and Information Technologies	3
Springer	Informatics and the Digital Society	3

TABLE VII. Conferences

Database	***Conference***	***Selected publications***
IEEE	FIE, Frontiers in Education Conference	21
ACM	ACM SIGPLAN conference on Object-oriented programming, systems, languages, and applications (OOPSLA)	15
ACM	SIGCSE technical symposium on Computer science education	10
ACM	ITICSE- SIGCSE/SIGCUE ITiCSE conference on Innovation and technology in computer science education (p. 180).	9
ACM	European Conference on Object-Oriented Programming	7
ACM / IEEE	International Conference on Model Driven Engineering Languages and Systems	7
ACM	Annual Southeast regional conference.	5
IEEE	IEEE Global Engineering Education Conference (EDUCON)	4
ACM	International workshop on Computing education research	3
Springer	Informatics and the Digital Society	3
Springer	IFIP World Conference on Computers in Education.	3

TABLE VIII. Data Items

ID	***Data element***	***Selected publications***
D1	Year	RQ1, RQ2
D2	Venue (journal or event name)	RQ1
D3	Publisher	RQ1
D4	Type of Publication (journal or conference)	RQ1, RQ2
D5	Research Approach	RQ2

This same period recorded a slight growth in the number of studies published in journals (0-5 per year). However, the final record for 2020 shows, except for 2021, an overall growth trend in the last five years.

Figure 3 presents a chronological arrangement of the primary studies, categorizing them by editorial source and illustrating the annual publication count. The significant increase in OOD research publications in 2008 likely reflects advancements in programming languages and methodologies embracing OOD

principles. Influential conferences and publications during that year also contributed to this surge. We plan to explore these factors further in future work.

The findings indicate that IEEE FIE (Frontiers in Education) conference is the predominant publisher preferred by authors in this research area. Key sources include the ACM Journal of Computing Sciences in Colleges, the ACM Journal of Computing Sciences in Colleges, ACM SIGCSE Bulletin, and the ACM SIGPLAN Conference on Object-Oriented Programming, Systems, Languages, and Applications. in journals grew significantly, reaching the maximum (14) recorded over the years. The year 2012 presents the exceptional situation of not registering articles of any kind. Finally, after a reduction in previous years, the most recent period (2013-2021) shows a significant growth in the number of studies published in conferences, reaching a maximum (11).

RQ2 - WHAT ARE THE APPROACHES THAT WERE REPORTED IN OODE RESEARCH?

This research question aims to identify trends in studies that focus on improving education in OOD. Table IX displays the distribution of papers across various categories, with the total number exceeding the overall count of selected studies due to some papers addressing multiple focuses. A significant portion of the papers falls under the teaching category, encompassing teaching tools (72), examples (42), and pedagogical approaches (23). Table IX reveals that a vast majority (160) of the chosen studies are classified within this teaching category. A substantial number of papers (67) concentrate on the curriculum, with the primary focus being on the curriculum content (agenda) and programming languages employed in teaching object-oriented thinking. Interestingly, we discovered a smaller number of papers (23) centered on assessment, a critical component for measuring and enhancing education in any domain. The smallest of the broad topic areas is students (12), this should be considered as an area of opportunity since aspects such as student attitudes, student behavior, or student engagement should be the subject of more study to improve the learning process. Since most of the papers fall into the teaching category, we created Table X. This table shows the number of papers that focus on each of the teaching category points of interest within each of the time periods analyzed.

Access to Reviewed Publications: Due to the extensive number of articles reviewed in this study and the space constraints of this report, we have not included detailed references for the 228 publications directly in this document. It will publish in future works. In the meantime, interested parties may request the full list of references directly from the authors.

TABLE IX. PRIMARY STUDIES ACCORDING TO MAIN CONTRIBUTIONS

Period	***Student***	***Teaching***	***Curriculum***	***Assessment***	***Total***
1988-1995	1	9	6		16
1996-2000		22	14	2	38
2001-2005	4	32	19	4	59
2006-2010	5	42	13	4	64
2011-2015	1	20	7	2	30
2016-2021	1	35	8	11	55
Total	12	160	67	23	262

TABLE X. NUMBER OF PRIMARY STUDIES ACCORDING TO MAIN CONTRIBUTIONS CONSIDERING JUST TEACHING APPROACH

Publisher	***Publications***
Teaching tool	72
Teaching examples	42
Pedagogical approaches	23
Teaching techniques or activities	23
Teaching methodologies, frameworks, perspectives, theories, or models	10
Total	160

V. CONCLUSION AND FUTURE WORK

Our aim in conducting this systematic mapping study was to provide insight into the evolution and current state of object-oriented design education (OODE), highlighting a shift towards more interactive and student-centered pedagogies. Despite recent advancements in OOD, there remains a critical need for more empirical research to validate and refine various educational methods strategies. The insights from this study provide a foundational understanding that can guide future research and curriculum development aimed at enhancing the efficacy and relevance of OODE. Our future work will focus on extracting more detailed information from our primary studies, particularly on the impact of emerging technologies on learning outcomes in OOD. Our findings can be used to enhance OOD education by integrating identified trends into curriculum design, teaching methodologies, and student engagement strategies. For instance, highlighting advancements and key publications can provide historical context to students, while incorporating case studies and real-world examples can make learning more relevant. This work-in-progress paper provides preliminary insights, and we plan to develop specific teaching strategies and curriculum recommendations based on our findings in future work to better align OOD education with current research trends and industry needs. Detailed findings and comprehensive analyses will be documented in subsequent reports.

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