

P4: Principles, Patterns, Practices, and Projects for Effective Software Engineering Education

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Abstract—Software Engineering education involves balancing theory and practice to produce industry-ready students who are not only proficient with various computer science concepts but also understand how to apply them in real-world scenarios. However, finding an appropriate balance between the two aspects is not an easy task for educators because of the challenges of theory-based teaching and industry demand in terms of applied skills and experience. In this paper, we discuss P4, a novel approach to designing software engineering courses and programs for computer science and software engineering students. P4 has been developed and incorporated into the Applied Software Engineering program at Northern Kentucky University. The proposed approach focuses on four pillars, that is, principles, patterns, practices, and projects, which are utilized as a consistent theme in all the courses of the curriculum. In P4, principles are foundational concepts that students are expected to know and be proficient with. Subsequently, students are taught patterns, i.e., solutions that can be applied to address specific design or development problems. Then, the approach highlights the importance of learning and using software engineering practices, which, in turn, enable achieving a repeatable process focused on quality improvement. Finally, P4 involves real-world software products as project activities.

Keywords—software engineering; education; best practices.

I. INTRODUCTION

Bridging the gap between theory and practice in Computer Science education is a well-known and multi-faceted challenge that has significant implications for both the industry and academia [1]. This is especially true in Software Engineering (SE) education, where it is crucial to provide students with a solid understanding of theoretical concepts and programming fundamentals while simultaneously engaging them in hands-on experiences that equip them to be professional software engineers prepared for real-world professional environments.

From the industry perspective, employers increasingly demand graduates who are technically competent and ready to perform on the job immediately without additional training to bridge the practice gap. Providing students with opportunities for the development of practical skills impacts key metrics such as employability, the perceived value of the degree, and ultimately enrollment [2] [3].

Most educational institutions have addressed this need by adopting different strategies, devising new programs, revising courses, and introducing experiential learning initiatives such as co-ops and internships. Unfortunately,

the rapidly evolving nature of the software industry often outpaces curriculum development, which leads to a scenario where either theoretical concepts and programming fundamentals are not always sufficiently covered, or the applied part of the material taught in classrooms fails to keep pace with the latest trends, tools, and practices. As a result, upon graduation, students may find themselves well-versed in theoretical knowledge but lacking in practical, industry-relevant skills, or vice versa [4].

Northern Kentucky University (NKU), a regional university where more than 50% of faculty time is dedicated to teaching, is uniquely positioned in the Greater Cincinnati area and in the Tri-State region (i.e., Kentucky, Indiana, and Ohio), and it serves a population mostly consisting of first-generation students. NKU's CS graduates primarily aspire towards software development roles in the regional tech industry. In 2018, the CS department decided to expand its offering, which already included degrees in Computer Science, Data Science, Computer Information Technology, and Cybersecurity, to make its programs even more relevant to its students. To this end, it launched the BS degree in Applied Software Engineering (ASE), which was specifically designed to address the local industry's growing demand for job-ready graduates [5].

Besides the crucial task of integrating theoretical knowledge with practical application, the development of the ASE curriculum also involved the challenge of distinguishing this program from the existing CS degree in a way that could be clearly communicated to current and prospective students to highlight the pros and cons of each degree to ensure clarity and informed decision-making. At the same time, as a newly established degree, the ASE program presented an ideal opportunity to innovate and adopt educational methodologies and new approaches co-developed with both students and industry leaders to specifically address their needs and expectations [5].

In this paper, we present P4, an approach for software engineering education founded on four core pillars: Principles, Patterns, Practices, and Projects. This strategy, which seeks to establish a progressive path between theoretical understanding and practical application, has been incorporated into the design across all the courses within the ASE program, and it provides instructors with a consistent methodology for developing courses and maintaining them aligned with the mission of the program. Furthermore, the P4 strategy helps integrate the curricular content of the

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