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Doctoral Education Process and Product Using Constructive Alignment in Software Engineering and Computer Science

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Abstract

Sweden is seen as one of the most research-driven and educated countries in the world. Thus, doctoral education is considered one of the most important elements of higher education in Sweden. This paper reflects upon the process and product of doctoral education in Computer Science and Software Engineering in Sweden. The paper provides an overview of doctoral education in Sweden, followed by a practical demonstration of how supervisors and doctoral students could use constructive alignment to achieve the learning outcomes of doctoral education using learning strategies and assessment methods to evaluate the learning activities and, by extension, the learning outcomes.

Keywords: *Computer Science, Constructive Alignment, Doctoral Education, Pedagogy, Software Engineering*

Swedish Abstract

Sverige ses som ett av de mest forskningsdrivna och utbildade länderna i världen. Forskarutbildningen anses därmed vara en av Sveriges viktigaste delar av den högre utbildningen. Detta ställningstagande reflekterar över forskarutbildningens process och produkt i Datavetenskap och programvarusystem i Sverige. Artikeln ger en översikt över forskarutbildningen i Sverige, följt av en praktisk demonstration av hur handledare och doktorander kan använda konstruktiv anpassning för att uppnå lärandemålen för forskarutbildningen med hjälp av inlärningsaktiviteter och bedömningsmetoder för att utvärdera lärandeaktiviteterna och i förlängningen lärandemålen.

Nyckelord: datavetenskap, doktorandutbildning, konstruktiv länkning, mjukvaruutveckling, pedagogik,

Introduction to Doctoral Education in Sweden

The term *Doctor of Philosophy* was first introduced in Sweden in 1864. This title was confirmed in a process called promotion, unlike the current case where the term *doctor* is used as an educational degree (Brodin et al., 2020). The foundation of these programs, which includes supervision and seminars, could be traced back to 1890. However, it is claimed that the term *doctoral education* was not established in Sweden until the 1950s (Odén, 2000). The number of doctoral students in Sweden has varied between 2,000 and 4,000 since 1970; however, this number increased from 13,000 to 20,000 between 1990 and 2005. As far as gender distribution is concerned in doctoral education, this varies from discipline to discipline. Women are in the majority in doctoral education in medicine, the social sciences, agriculture sciences, and humanities, while there are considerably more male doctoral students in natural science and technology (Brodin et al., 2020).

Swedish doctoral education is governed by a complex set of rules regulated by gradual changes to the Higher Education Act (Nya Högskoleförordningen, 1993; Statutes, 1993). The most noteworthy changes relating to Swedish doctoral education came as part of the Bologna process, and learning outcomes were introduced in the Higher Education Ordinance for licentiate and doctoral education in 2007. There are several stakeholders with different responsibilities involved in this process. The doctoral students are responsible for the content of their study, with the supervisor in the role of teacher. Moreover, the head of the department is responsible for the regulations relating to doctoral students' employment. Besides these regulations, the relationship between student and supervisor is often affected by contracts and verbal agreements related to research findings and research (Brodin et al., 2020). It is essential to highlight that the supervisor is not considered a controller of the student even if that supervisor is responsible for the designated project. The doctoral education is a time-limited position and must cease after four years. However, if the students do not complete their doctoral education in four years, they retain the right to supervision support even after that time (Brodin et al., 2020). A typical distribution of doctoral education entails four years of research (80%) and one year of departmental duties (20%).

Underlying Theoretical Framework for Doctoral Studies in Software Engineering and Computer Science

Several theoretical frameworks are found in the literature to achieve the desired teaching and learning outcomes (Benner, 1984; Wächter, 2004). However, I have selected constructive alignment as a theoretical framework to explain the quality characteristics of doctoral education in software engineering and computer science (Biggs, 1996; Tang & Biggs, 2007). Constructive alignment is the underlying concept behind the current program specifications, learning outcomes, and the assessment criteria used for the evaluation of learning outcomes (see Figure 1). The reason for choosing constructive alignment is that it allows the students to objectively define the learning outcomes, the work activities to achieve those learning outcomes, and the assessment of activities in the light of learning outcomes. These three components correspond well with the practical nature of research problems solved in software and engineering, and computer science. This paper maps a doctoral thesis on constructive alignment. Furthermore, the paper will demonstrate a constructive alignment-based proposal for an ongoing Ph.D. position that I am supervising as a co-supervisor.

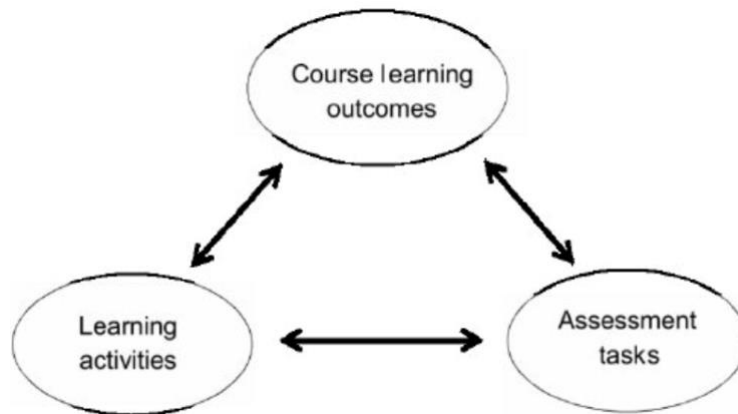


Figure 1: Constructive alignment (Biggs and Tang, 2007)

Characteristics of Doctoral Thesis in Software Engineering and Computer Science

This section will explain the key phases of doctoral education in software engineering and computer science. Typically, a Ph.D. in engineering education is divided into three phases (see Figure 2):

1. Problem exploration
2. A proposed solution to the problem
3. Validation of a proposed solution

The problem exploration phase is a starting point for a Ph.D. student to dive into the literature pertaining to the scope of the Ph.D. position. Typically, this phase starts with a systematic literature review of the field to find state-of-the-art evidence in a given research area. It allows the student to grasp extant literature and identify research gaps for future research. Essentially, the systematic review of the field paves the way for future studies in doctoral education. The main outcome of the phase is to know the research problems to which the research community is seeking solutions.

Once the key research gaps/ problems are identified, the next step will be to start looking into existing solutions for possible improvement or creating a new solution for the given problem. This phase requires the student to conduct exploratory pilot studies to check the feasibility of the existing solutions or the possibility of developing a more efficient one. This may include collecting firsthand data from the industry and running pilot studies to see the early potential of the proposed solution. If the proposed solution shows promise, this extends into a detailed implementation of that solution with all the underlying assumptions and conditions. The key outcome of this phase is a well-defined specification of the problem and implementation of the specifications.

The final step in the thesis is to evaluate the proposed solution contra existing solutions in terms of the proposed solution's accuracy and application in the real-world context (Smith, 2008). This step typically involves either a static or dynamic solution validation. In static validation, the solution is discussed with domain experts to check whether it has the claimed significance, while dynamic validation is performed by running the solution in the real-world context. The data collected based on running the solution in the real-world context determine the effectiveness and application of the proposed problems. It is also essential to discuss the possible limitations of the proposed solution and what could be done in future research to improve it.

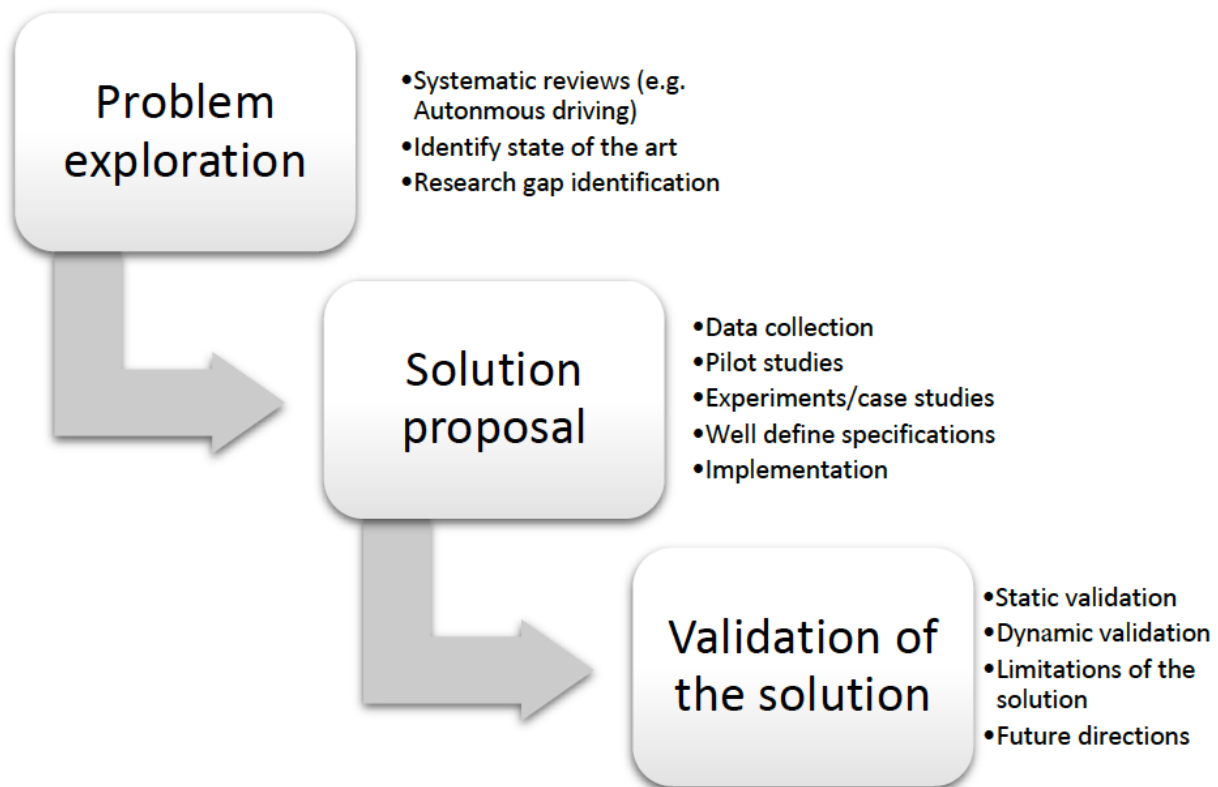


Figure 2: Key phases of doctoral studies in SE and CS.

Mapping of Doctoral Educational Activities on Constructive Alignment

This section shows the demonstration of constructive alignment using an ongoing Ph.D. position on autonomous driving. I am working as a co-supervisor for this Ph.D. position and take this opportunity to reflect on my understanding of how the Ph.D. student should progress during the doctoral education to achieve the desired learning outcomes. Based on my experience and learning outcomes of doctoral education from Brodin et al., 2020, I have identified four learning outcomes for the Ph.D. position on autonomous driving based on a constructive alignment framework, which is as follows:

1. Systematic understating of the extant literature to find research gaps.
2. Understanding and application of different research strategies, such as systematic revision, case studies, experiments, design science, etc.
3. Graduation of an independent researcher in the field after finishing the doctoral education
4. Development of pedagogical skills

The first three learning outcomes can be achieved through three research phases: problem exploration, solution proposal, and evaluation of the proposed solution (see Figure 2). The coursework in teaching and learning activities is divided into two parts. The first part of course work is geared towards learning different research strategies and their application in solving the autonomous driving problem. The second part of the course work focuses on developing the teaching skills to excel as a teacher in higher education teaching and learning. The assessment of these learning outcomes can be measured with the help of the number of publications in the conferences and journals relevant to autonomous driving. Furthermore, the student can show their gradual maturity as a researcher by attending internal seminars and using these events to prepare for the final Ph.D.

defense. The development of a doctoral student can be assessed based on the performance of the student in the pedagogical courses attended at the university.

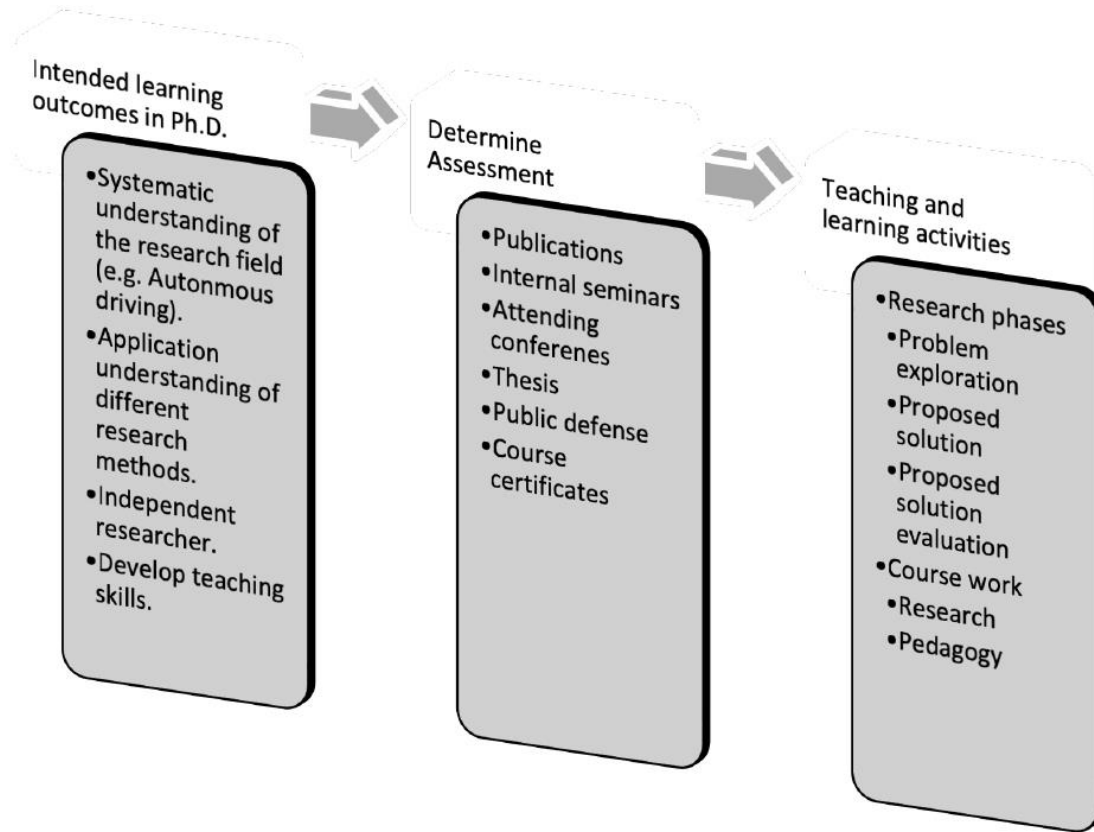


Figure 3: Mapping of constructive alignment on doctoral education in SE and CS

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