



Developing and improving competence profiles of project teams in engineering education

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ABSTRACT

This concept paper reflects an ongoing research on designing students' team projects in engineering education with a focus on soft skills development. The core idea is to relate project tasks with relevant team situations and team roles which require and train certain sets of soft skills. The paper proposes: a) a model for developing the relevant soft skills out of project tasks, and b) an approach to relate individual competence profiles of team members with an overall team competence profile. A core assumption is that if a team is formed, individual competences are aggregated in a certain way to form a single team competence profile. However, in the case of soft skills this aggregating is more complex than simply adding skill levels, e.g., soft skills in teams are a result of specific combinations of competences. Understanding these effects is relevant for project management and engineering education. The paper proposes a first draft of a systematic framework for investigating such effects and for making them usable for the design of student projects in engineering education. It also provides insight into an example of an agile cross-border project conducted fully online and using the scrum method. The paper is considered to be a contribution to the development of project-based learning.

1 INTRODUCTION

For being competitive, “tomorrow” graduates would need to demonstrate technical, professional and global competences [1], including knowledge of project management as a part of “technical” competence. Since much engineering work is done in project and teams, the individual competences are the basis of the team’s or project’s competence profile – a kind of competence aggregation. However, the research on competences in project management indicates a more complex concept: individual competences do not just add up to an overall team competence. In general, there are competence profiles of individual team members which cumulatively scale up to the competence profile of the team; but this aggregation, we believe, is connected to the interaction of members’ soft skills. Human interaction is not an option but a necessity to share knowledge, experiences, and lessons within teams and between teams. Whereas technical skills can be acquired by an individual through learning and practice, soft skills require the interaction of others either through mentoring, interventions, or specific trainings to be developed. Consequently, team competence and performance depends on soft skills and team interaction while at the same time soft skills are formed and trained in such team situations. Our research should contribute to a better understanding of these effects and to ways to make such effects usable and applicable in engineering education.

2 RESEARCH MOTIVATION AND METHODOLOGY

We aim to contribute to existing research by proposing a concept on how the team member interactions can strengthen or weaken soft skills of the team. This will support the composition of student teams in project-based education and at the same time it will enable the project managers or project team leaders to have awareness of such interactions so they can strategically allocate team members to create team profiles. We acknowledge that technical skills of the team members are also of high importance in contributing to the effectiveness of the team competence.

Based on the structured literature research, this concept paper will:

- a) Propose a model for developing a competence profile of a team
- b) Propose a model for examining team competence profiles with focus on soft skills
- c) Propose an approach of conducting effective student team projects based on the analysis of the competence profiles and with a focus on soft skills development

3 LITERATURE RESEARCH

The concept of competences is a very diverse research area with different approaches towards definition. In their research on soft skills, Marin-Zapata et al. [2] provide a clear taxonomy “competence → competency → (skills, motivation, knowledge)”, where skills are distinguished between soft and hard; in its turn, hard skills refer to technical expertise, and based on the proposed taxonomy, soft skills have two main components as intrapersonal and interpersonal skills. The development of soft skills depends on the interaction between individual innate traits (i.e., personality and abilities) and contextual factors, whereas in organizations the



interaction between soft skills and training programs appears to be vital to enhancing employee job performance [2]. According to Maturro et al. [3], soft skills are a combination of the abilities, attitudes, habits, and personality traits that allow people to better perform in their workplace, complementing the technical skills required to do their jobs and influencing the way they behave and interact with others. Based on the systematic mapping study, Maturro et al. [3] provide main categories (including their definition) of soft skills relevant for software engineering; those are: communication skills, team work, analytical skills, organizational/planning skills, interpersonal skills, leadership, problem-solving skills, autonomy, decision-making, initiative, conflict management, change management, commitment/responsibility, stress management, customer orientation, flexibility, ethics, results orientation, time management, innovation, presentation skills, creativity, critical thinking, negotiation skills, listening skills, motivation, willingness to learn, fast learner, team management, and methodical skills category. Furthermore, Tam et al. [4] examined the people/soft factors that contribute to agile software project success, found that societal culture and personal characteristics of the team members can impact the overall capability of the team.

Although various studies have defined soft skills in different ways, there appears to be consensus that individual personality play a major role in influencing soft skills. Several factors can influence a person's personality like individual attitudes, behavioural habits, personality traits and their individual competences (abilities). In their study, Yilmaz et al. [5] assessed the personality characteristics of software development teams using the Big 5 personality theory; they discovered that effective team structures support teams with higher emotional stability, agreeableness, extroversion, and conscientiousness personality traits.

Awuor et al. [6] study skills for teamwork and propose an assessment methodology of teamwork competence; authors highlight that through teamwork and project-based learning, students improve their knowledge in technical, behaviour and contextual competence areas of project management, and the study revealed that thanks to teamwork, student competences in creativity, leadership and negotiation were sufficiently improved. In their study on project management learning and teaching challenges, Ojiako et al. [7] revealed key components of students' experiences: transferable skills (interpersonal skills, time management, curriculum coherence, critical thinking and communicating) and virtual learning (quality of e-resources, accessibility of information managed online); due to the nature of the study, the paper provides a detailed self-evaluation survey on transferable skills. The authors conclude that institutions and educators need to re-think an integration of transferable skills into education agenda and allow engagement in project-based modules, where students become proactive problem solvers and critical thinkers [7].

To improve students' performance in a project-based learning, Aranzabal et al. [8] propose a methodology to build a balanced project team. Using the Belbin's role theory to raise student awareness about the benefits of teamwork, authors confirm that teams formed based on one-of-nine roles performed better than self-selected teams. The role theory developed by Belbin in 2010 states that a team role is a "a

tendency to behave, contribute and interrelate with others in a particular way” and it is influenced by personality, mental abilities, current values and motivation, field constraints or external working environment, personal experience and cultural factors, and role learning. The authors highlight, that using the role theory, students realised a positive contribution to cooperative learning, interpersonal relationships, social skills, and abilities to work in the roles- and skills-based environment [8].

4 PROPOSED CONCEPTS

In our first concept (Fig. 1) we want to highlight different aspects influenced by hard/technical and soft skills. If we look at competences from a technical skills’ perspective, then we believe it is enough to add up such skills to compose a project team competence profile. Whereas when we consider competences from the soft skills’ perspective, it is not possible to add up soft skills of team members and a more complex interrelation among team individuals should be considered. Based on the task deliverables to be achieved (see $t_1 \dots t_n$) in Fig. 1), we may define roles ($r_1 \dots r_k$) and relevant competence profiles ($CP_1 - CP_m$). Based on taxonomy given by Marin-Zapata et al. [2], competences are composed of soft and technical skills, and since the soft skills do not complement each other between team members in a simple way, we assume that deriving the interpersonal team aspects and soft factors from the individual soft skills is an unsolved scientific problem. While we assume that accumulating the technical skills (see “+” in Fig. 1) of the individuals into a technical team competence profile is adequately done by really just adding skill levels, we expect that accumulating the soft skills (see “++” in Fig. 1) is not possible by just numerically adding skill levels but only by an expert review and assessment, based on the experience of good managers.

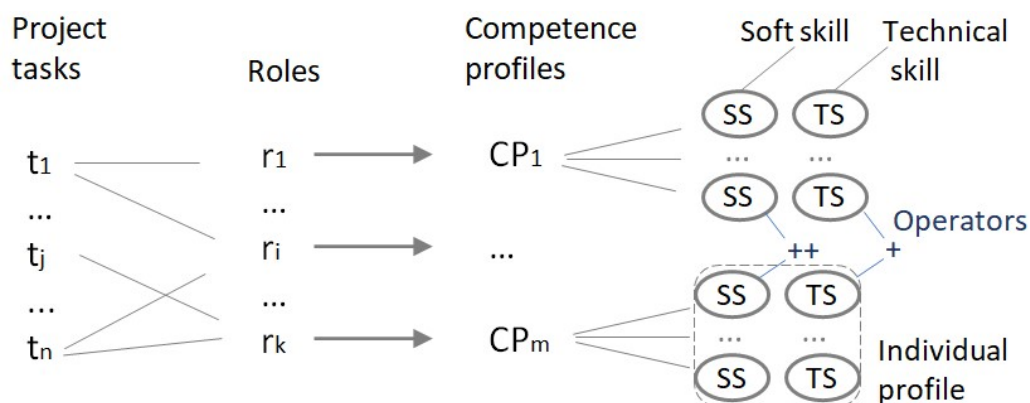


Fig. 1. A model for examining interrelations of project tasks, roles, technical and soft skills

As observed in the researched literature, a project team is comprised of individuals with various soft skills and different personality traits. It can happen that the personality traits of team members clash and, in one or another way, impact the team performance. But if the personality traits are aligned, it can lead to creating an effective working team. Therefore, we propose a second concept model (Fig. 2) to investigate factors that play a role in development of soft skills in teams. The model acknowledges

the significant work done by existing research on team formation, but our aim is to find a way to select and allocate team members to form balanced teams. Through considering the personality traits of the team members, we aim to formulate team competence profiles that can be used both in education and project staffing for combining team members with the right set of soft skills and for developing soft skills by working in such teams. As highlighted in [4], [7] and [8] soft skills can be trained through doing projects in teams, and as claimed in [5], team capability refers to the utilisation of knowledge, which, we believe, can be fostered by trust developed over time.

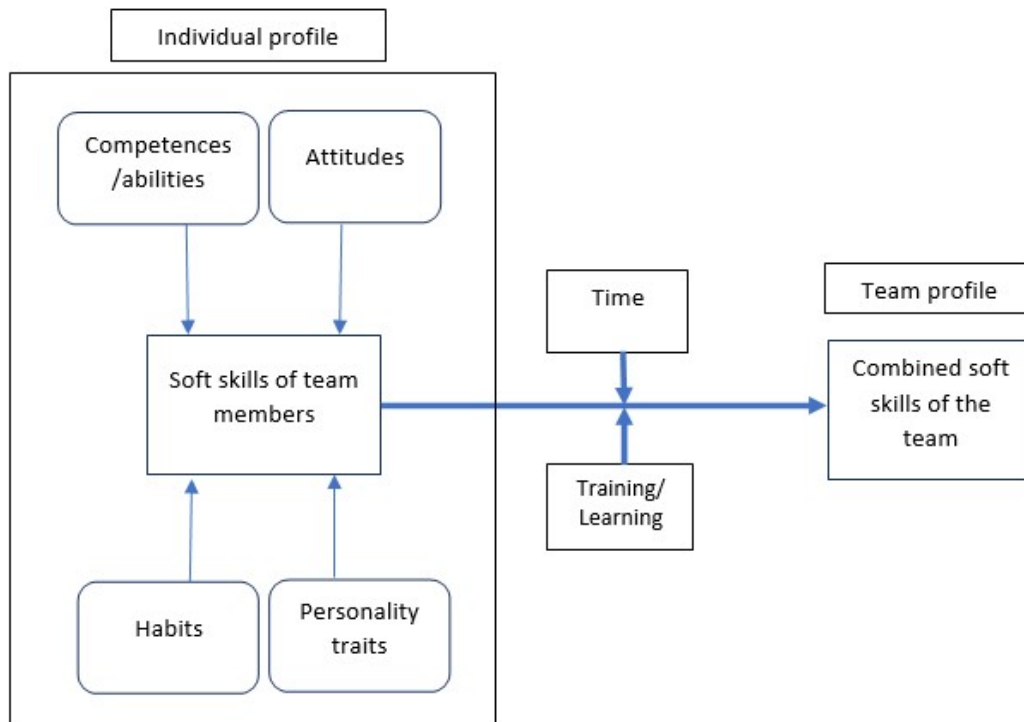


Fig. 2. A model for examining team competence profiles with focus on soft skills

Each team member has their own personality traits which can impact the way they associate with other team members, hence, impact the transfer of skills between them. This model proposes that the interrelation and transfer of soft skills between team members is influenced either negatively or positively by individual personality traits, thus, impact the overall soft skills of the team positively or negatively. In Table 1 we summarise meanings of personality traits and relevant scores to be considered when forming the team.

Our research is investigating methods and tools for composing “good” teams for a given project (set of tasks) as shown in Fig. 1 and for solving the problem of deriving the soft factors from individual soft skills by using more complex concepts like personality traits (see Fig. 2). After the elements and relations of these two conceptual models are properly investigated, we aim to incorporate the developed team formation approaches into engineering education. This can be enabled through project-based education and competence-based description of desired learning outcomes. Based on specific soft skills which are supposed to be trained, projects are constructed (or

selected) which provide the learning settings and team situations needed to train the soft skills. The success depends on forming student teams with the right combination of individual competence profiles. In the next chapter, we will propose how such an approach could look like in an educational framework for project-based learning.

Table 1. Personality traits: meaning and measures (based on [5])

Dimension	Meaning	Score in the questionnaire
Extroversion	is the personality trait of seeking fulfillment from sources outside the self or in community	high scorers tend to be very social while low scorers prefer to work on their projects alone
Agreeableness	reflects many individuals adjust their behavior to suit others	high scorers are typically polite and like people, while low scorers tend to 'tell it like it is'
Conscientiousness	is the personality trait of being honest and hardworking	high scorers tend to follow rules and prefer clean homes, while low scorers may be messy and cheat others
Neuroticism	is the personality trait of being emotional	high scorers experience negative emotional state, sadness and anxiety, while low scorers emotionally more stable and even risk takers
Openness to Experience	is the personality trait of seeking new experience and intellectual pursuits	high scores may daydream a lot, while low scorers may be very down to earth.

5 PROPOSED APPROACH AND DISCUSSIONS

Rajala [1] provided a 3-D global engineer framework and described attributes of technical, professional and global competences required for future engineering graduates if they want to succeed. Our proposed approach aims to develop students' team projects which contain team situations – and respectively learning situations – which require a set of professional and global competences in connection with a technical tasks which requires technical competences. Engineering students conduct the technical tasks and inherently get into the team-related learning situations which train their soft skills. The project and learning design considers the connections between tasks, team roles, competence profiles, soft skills, and hard skills as described in Fig. 1.

Our research and the respective student projects are embedded into a cooperation (European Partnership for Project and Innovation Management – EuroPIM) between a number of European Master's programmes in IT, engineering and project management which gives us the chance to form international and interdisciplinary teams [9]. In this setting, we are developing a guideline on how to construct (or select) project cases and how to form student teams based on the intended learning outcome, specifically looking at the soft skills.

As an example, we refer to the development of an mobile app in teams of 4-5 students (mixed from two different countries) which was conducted in agile sprints, using the scrum method, in a 100% online setup [10]. This format was conducted and evaluated several times within the EuroPIM partnership.

The scrum project foresees individual work of the students and collaboration is happening only in specific team situations, the so-called scrum ceremonies. The scrum ceremonies are the relevant learning situations with respect to soft skills. In addition, this type of project foresees only 3 team roles: the scrum master who is a process-focussed facilitator and coach, the product owner who is a result-focussed driver and shaper, and the team members who are considered to be a group of equals. Therefore, the scrum ceremonies can be considered as tasks (see Fig. 1) which contain specific team situations (see description of the 5 ceremonies in Fig. 3) which are connected to specific soft skills (see [10]).

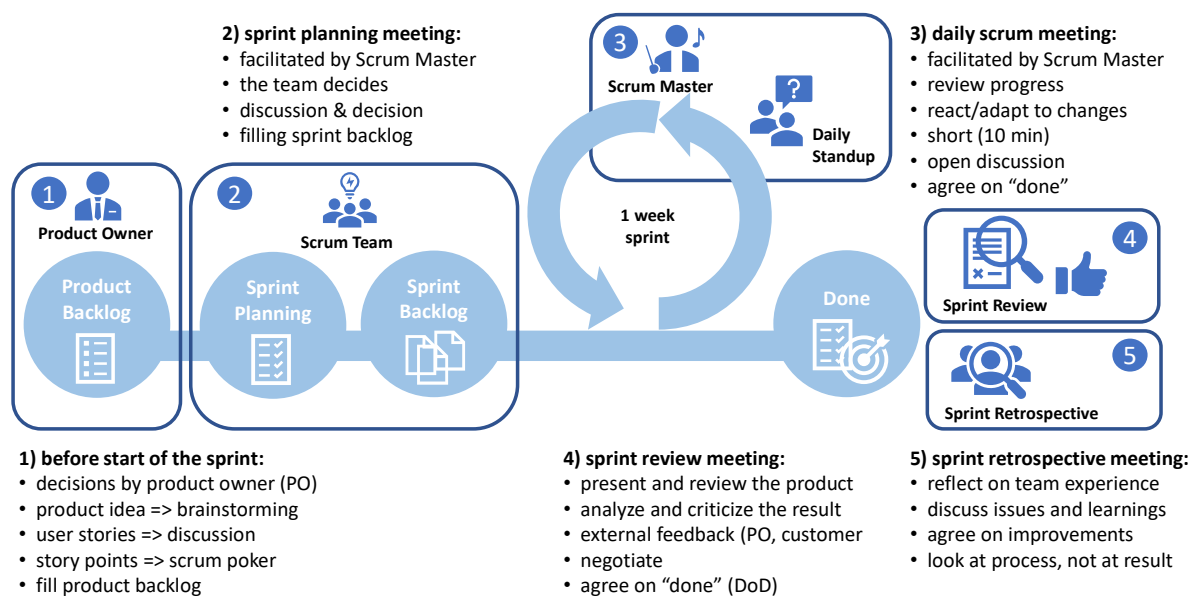


Fig. 3. Analysis of the 5 scrum ceremonies regarding team situations and team roles [10]

Based on the experience, we propose a 5-step approach for designing international and interdisciplinary cross-border projects where students from different backgrounds and cultures can train technical, professional and global competences.

1) Before the course:

- Based on the planned learning of the course, define a possible case study to stimulate a relevant project scenario (preferably with industry involvement, e.g. the development of an mobile app as in [10])
- Define the list of project tasks to be performed by the team within the course → Tasks will determine the roles of the team members → in case of the scrum project (Fig. 3) these are the 5 scrum ceremonies and the 3 scrum roles which are part of the project.
- Design a self-evaluation questionnaire for the students to assess their soft skills before doing the course (e.g., as a catalogue of soft skills, the list provided by Matturro et al. [3] can be used; questions may be adapted from [7]) → initial profiles of students
- Based on the required team roles, define which students will be assigned to a specific team and which role each student may perform in order to fulfil the project tasks → this is an initial assignment which will be refined at the beginning of the course

- Plan the intended learning outcomes based on the initial profiles of the students and the anticipated project (learning) situation during the project
- 2) At the beginning of the course:
 - Perform a team building exercise with each student team in order to define the set roles for the project → build a balanced team (based on personality traits assessment [5] or Belbin's role theory [8])
 - Invite company representative to provide the case → create a realistic project kick-off situation (e.g. in the discussion of user stories, see (1) in Fig. 3)
 - Reflect with students on the experience during team building and project kick-off and ask them to refine their self-assessment
 - 3) During the course
 - Provide students with project management methodology → training of technical competence (e.g. a scrum training and test)
 - Provide students with tailored soft skills trainings and knowledge
 - Project work in cross-border (cross-cultural) teams → training of global and professional competences
 - If required, conduct team exercises, e.g. for conflict resolution
 - 4) At the end of the course:
 - Organise reviews (e.g. pitches, feedback sessions) with company representative → training of professional competence
 - Assess the quality of the project results → evaluation of technical competence (e.g. in the sprint review in Fig. 3)
 - Conduct the self-evaluation survey on acquired soft skills → evaluation of the soft skills gap closed during the course (examples: see Fig. 4)

9

How much would you agree to the following statements about using projects as a educational format (called project-based learning (PjBL) and cooperative online international learning (COIL)) *

	not at all	not really	neutral	to some extent	to a large extent	don't know
Such projects are relevant and useful for my competence development	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>			
Such projects are particularly good for soft skills development	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>			
The virtual collaboration was especially good for competence development	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>			
This event/course supports my international, intercultural and language competence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>			
I increased my competence in project work and project management	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>			
My IT skills improved	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>			
According to my experience my competence gain is depending on the team role I took in the project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>			
According to my experience my competence gain is depending on the other team members	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>			
The project case study (app development) supported the learning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>			
Do you believe that the type of project is relevant for the competence gain	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>			

12

Reflecting on your experience in this course, how would you rate your competence in the following **soft skills after taking the course?** *

	no skill	somewhat skilled	neutral	highly-skilled	very highly-skilled	don't know
Analytical skills	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Problem-solving skills	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

8

To what extent did you develop the following **abilities/competences** during the assignment? *

	not at all	not really	neutral	to some extent	to a large extent	don't know
The ability to complete group assignments with students from other study programs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
The ability to work in international project teams	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>

Fig. 4. Examples of survey questionnaires used in the agile cross-border projects

5) After the course:

- Lessons learned workshop in order to reflect on the team situations and to raise the awareness of students for the soft factors

Our research is based on conducting student projects using above-mentioned 5-step approach. We conducted several trial runs with student teams from 2 countries (e.g. Germany-Kazakhstan [10], Germany-Spain) and participants numbers from 10-50. Evaluations showed positive feedback of students and teachers though some results were surprising (e.g. English language communication was a minor problem, while IT literacy was partly challenging). At the next step we aim at evaluating the impact on students' soft skills based on survey results and expert reviews. For this we intend to refine the methodology and to validate the concepts and quality of the methods based on conducting student projects within our European consortium.

6 SUMMARY

Designing student team projects with specific team situations in mind can support the development of soft skills of engineering students. Nevertheless, a straight-forward methodology for connecting project tasks, students' team roles, learning situations and soft skills in a meaningful learning design is a challenging task. The proposed 5-step approach is a first draft of a systematic framework which might finally support teachers and students in systematically increasing the learning outcomes in project-based learning, especially with respect to soft skills.

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