*Sindh Univ. Res. Jour. (Sci. Ser.) Vol. 50 (001) 53-58 (2018)*
http://doi.org/10.26692/sujo/2018.01.0009
**SINDH UNIVERSITY RESEARCH JOURNAL (SCIENCE SERIES)**

# KSAO Framework for Computer Science Project Student Teams

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Received 20th June 2017 and Revised 24th December 2017

**Abstract:** None of the existing Knowledge, skills, abilities and other factors (KSAO) frameworks have included task work skills as KSAO factors; all of them only proposes teamwork KSAO factors. Moreover, all of these frameworks were proposed for professional teams only. The aim of this research is to propose a KSAO framework for computer science capstone project student teams; the framework not only have the teamwork skill component but the taskwork skill component as well. Research papers on technology students, capstone projects, self-managing teams and KSAO frameworks are analyzed comprehensively so as to give rise to a framework that is presented here. The methodology followed is qualitative thematic analysis. The framework is developed as part of a doctoral thesis for guiding the identification of team building criterion for building computer science capstone student project teams and for developing an automated intelligent software for assisting students in team building.

**Keywords:** KSAO, capstone projects, computer science, thematic analysis

## 1. INTRODUCTION

All organizations comprise of teams of people that work on tasks together, instead of working individually (Rousseau *et al*, 2006, Devine *et al*, 1999). A peculiar team consist of individuals working in constellations to perform projects and assignments that require a collective effort. Alternatively speaking, a team is a recognized and stable entity of interdependent people that are mutually responsible for achieving different jobs in an organization (Sundstrom *et. al*, 1990; Gladstein, 1984). In any organizational setup, team-members' attributes may be divided into "task-work related and teamwork related" (McIntyre *et al*, 1995). Task work attributes assists individuals and thus the teams, in the technical functions performed by the team members (Morgan *et al*, 1993). Task work attributes affect directly the accomplishment of the assigned tasks. On the other hand, teamwork attributes are important elements for teamwork (Cannon-Bowers *et al*, 1995) and they represent everything from the interpersonal skills, personality, to conflict management skills etc. (Rousseau *et al*, 2006). Teamwork attributes are a necessity for effective team performance (Taggar *et al*, 2001). The collective nature of teamwork attributes and task work attributes implies that teamwork is interdependent on task accomplishment (thus on task work), which requires aligning and coordinating technical expertise of individuals while keeping the team members together (Bowers *et al*, 1993; McIntyre *et al*, 1995; Murphy *et al*, 1995). Teamwork and task work attributes affect team performance and team cohesion directly. Teamwork behavior is a multi-faceted notion that is challenging to theorize however all frameworks available in the literature focuses only on teamwork behavior. Research literature contains several frameworks **(Fig. 1)** that proposes one or the other teamwork attributes as the most necessary ones for keeping a team together. These frameworks are normally termed as Knowledge, Skills, Abilities and Other factors frameworks (KSAO) in the literature. The KSAOs presented by various authors differ to some extent, however a substantial overlap can be identified. Several major limitations in the literature on KSAO frameworks proposed by various researchers can be identified which includes(a) absence of any KSAO framework for the student teams, and(b) no task work attributes are ever recognized or proposed as KSAOs in the available frameworks. It is not that the authors of the available KSAOs does not acknowledge the importance of task work KSAOs. For example, Stevens *et al*, (1994) notes while defending the importance of task work KSAs that "…in fact, because of the enhanced requirements for flexibility and versatility in teamwork settings, the demand that team members have a breadth of technical KSAs is often greater." Noticing the absence of KSAO framework for capstone project student teams and absence of recognition of task work KSAOs in the available literature, this current research fills these gaps by proposing a single framework for computer science capstone project teams with both the teamwork attributes component and task work attributes component. The teamwork attributes are normally viewed as soft skills and technical skill as task work attributes in the literature.

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Campion, Medsker, and Higgs (1993): Communication, cooperation, social support;
Cannon-Bowers, Tannenbaum, Salas, and Volpe (1995): Adaptability, communication, coordination, decision making,interpersonal relations, performance monitoring and feedback, shared situational awareness;
Carson, Mosley, and Boyar (2004): Rehearsal, self-criticism, self-expectation, self–goal setting, self-observation/evaluation, self-reinforcement;
Cohen (1994) Coordination, implementation of innovation, sharing of expertise;

**Fig. 1: Some KSAO Frameworks (Due to space constraints, view all frameworks with references in Rousseau *et al,* 2006)**

A KSAO framework for student capstone project teams was found necessary for guidance whilst conducting a doctoral research by the first author, aim of which was to identify which criterions are necessary for computer science capstone student project team building. This current research for developing KSAO framework for computer science capstone project student teams is deeply motivated by the works of Stevens *et al.,* (1994) and Marks *et al.,* (2001); the methodology adopted for this research also parallels these above mentioned influential researches. proposed a KSAO framework for professional teams; also proposed a temporally based framework for professional teams however that was developed by synthesizing the already available frameworks of team processes in the literature. As mentioned above, all available KSAO frameworks (including that of (Stevens, *et al.,* (1994). don't have any factors describing the task work attributes, (b) none of them were developed for student teams (c) nor any of them were developed for computer science capstone project teams. The framework proposed in this research fills these gaps.

## 2. DEVELOPMENT OF THE FRAMEWORK

The basic objective of the proposition of KSAO framework for computer science capstone project student teams is to propose a framework that is comprehensive enough to apply to different types of teams of computer science students; another objective is to make it as easy to understand for applied research as possible. The framework is proposed by: (a) Comprehensively reviewing the literature on computer science student teams as well as other technology related student teams, capstone projects, and existing KSAO frameworks (b) Using previous KSAO frameworks proposed for professional teams for understanding the structure suitable for the proposed framework, and (c) By integrating our applied experiences with computer science capstone student teams. **(Table 1)** displays the proposed KSAO framework. This framework is a comprehensive effort because it has been based on findings from the literature available on technology student teams. The framework consists of a hierarchical structure. The nine first order KSAO factors are categorized under two major themes, i.e. teamwork attributes and task work attributes. This framework is later used for identifying second-order factors that are termed as team building criterions (these second-order factors are not the subject of this paper however they are available in the doctoral thesis of the first author of this paper.) Although much thought is given whilst developing this framework, however it is still possible that some factors specific to a very peculiar type of team may not have been included in our framework.

Thematic analysis is used for identification of first order factors outlined in the KSAO framework proposed in this paper. Thematic analysis revolves around identification of themes, therefore it is necessary to explain what a theme is. Joffe (2011) notes that a theme signifies the presence of a specific pattern found in a data set. The theme can be very obvious, that is something directly observable. Alternatively the themes can be more latent and implicit. Themes can either be drawn from "a theoretical idea that the researcher brings to the research (termed deductive) or from the raw data itself (termed inductive) (Joffe, 1999)."Theoretically derived themes are useful for extending, refuting or replicating existing studies (Boyatzis, 1998) whereas latent thematizingis useful for 'revolutionizing knowledge' of the topic under investigation by identifying new themes (Joffe, 2011).

**Table 1: KSAOs Framework for Computer Science Capstone Project Student's teams**

| |
|---|
| **Teamwork or Soft Skills** |
| 1. Interpersonal/social skills |
| 2. Conflict management skills |
| 3. Collaborative problem solving skills |
| 4. Individual self-management skills |
| 5. Personality |
| **Taskwork or Technical Skills** |
| 1. Software Project management skills |
| 2. Task work expertise |
| 3. Software Development Processes skills |
| 4. Work analysis & reflection |

## 3. KSAO FRAMEWORK FOR COMPUTER SCIENCE CAPSTONE PROJECT STUDENT TEAMS

The framework for student teams is shown in **(Table 1)**; no order is intended among the KSAO factors. The framework consist of nine subthemes categorized under two major themes. As mentioned earlier, the teamwork attributes are in-built in teamwork (Cannon-Bowers *et al,* 1995). Teamwork or soft skills

theme consist of those themes that are a combination of relational skills, societal skills, communication skills, personality traits, attitudes, and communication style among others. Teamwork attributes are a necessity for effective team performance (Taggar *et al,* 2001). Task work attributes affects the functional operations performed by team members (Morgan *et al,* 1993)and directly affect the completion of tasks. These attributes are related to the technical needs of a job irrespective of which organization it is carried out in and whether done as alone or as a group. The task work or technical skills theme consists of core expertise required to perform technical operations such as project management, software processes and design processes etc. A short description of each teamwork skills/attributes and task work skills delineated in the framework is available in **(Table2)**.

**Table 2: Short Description of KSAO Factors**

| **Team work Skills** |
|---|
| Interpersonal/Social Skills: Agreeable and harmonious association is necessary in all groups whether large or small and whether consisting of students or professionals; a harmonious relation spare members from facing challenges, conflicts and other issues (Annelies et al, 2001). Such a relation is a direct result of the interpersonal skills of the individual members of the team. Interpersonal skills ensures that there are fewer chances of estrangement, obstruction, and departure, from productive participation of team members (Annelies et al, 2001). Researchers are of the view that team's cohesion relies on the capability of each member to efficaciously cope with intra-team issues for which the individuals rely on their capability of "interpersonal competence and social skills" (Carron, 2000). Thus interpersonal skills can augment cohesion because interpersonal and social skills tend to produce attraction among members of a team, and this attraction is related to group cohesion (Colarelli et al, 1992). Celik et al (2013) noted that according to Johnson et al (2014) students' ability to work within a team as a group member is only possible by utilizing their interpersonal and social skills which also influences their employability, productivity, and career success. Interpersonal and social skills is one of the important skills in graduate students as delineated in Australian Computer Society's accreditation specifications (Keogh et al, 2009). |
| Conflict Management Skills: Conflicts are a direct result of flaws in team composition, lack of communication (Kaiser et al 1982; Salaway 1987; White et al, 1986) and occupational and cognitive differences among members of the teams. However, effective teams manage the conflicts instead of suppressing them so as to maintain seeming stability; effective teams deal with conflicts in constructive, civil, and not personally threatening way (Stevens et al, 1994). For managing conflicts appropriately, a honed conflict management skill is much desired in team members. Since conflicts have positive effects too such as lessening of stress in individual team members, they are the indication of lack of communication or they are the indications of the lack of innovation, etc. Therefore individuals must be good at noticing and rectifying conflicts instead of suppressing them and causing more harm to the project because if conflicts are allowed to stay longer, they can even disintegrate an otherwise stable team or heighten hostility, and cause reduced performance (Stevens et al, 1994). |
| Collaborative Problem Solving Skills: Brigid (2000) noted that when people are required to solve a problem together, they will be required to build a common frame of reference. This requires a collaboration between the team members. Brigid (2000) notes that in project teams, the demand for collaborative problem solving skill in each members is much greater than in individual-based work systems. Especially in self-managing teams, members are likely not to ask controllers to resolve issues, instead the team members take initiatives to solve them. Even in supervised teams, members are still required to contribute in solving problems. A big advantage of collaborative problem solving is if a solution to a problem is selected from several that were offered by various team members then the results will be better as compared to the solution conceived by an individual only (Brigid, 2000). This is described as intellective or disjunctive form of problem solving. Stevens et al (1994) notes that by including various team members in problem solving, numerous viewpoints are considered which may improve the diagnosis, the range of solutions available, and decrease the likelihood of incorrect solutions. For both professional as well as student teams, the team members should have the skills to involve team members in the collaborative problem solving process and encouraging the generation of alternative solutions, ensuring that all viewpoints are deliberated, and accepting only those solutions that are reinforced by suitable reasoning. |
| Individual Self-management Skills: Individual self-managing skill is related to an individual taking responsibility of own actions and managing them according to the need of the team. Individual self-management skills consists of attributes such as self-goal setting, self-rehearsal, self-problem assessment, punishment or self-reinforcement and self-observation and evaluation (Manz et al, 1984). Individual self-management is different from self-management of teams. Whereas individual self-management is related to individuals, self-managing teams operate independently from the supervision or have very little direct supervision. |
| Personality: This KSAO framework presented for computer science student teams is different from all other frameworks available in the literature in one more sense that it acknowledges 'personality' as a factor that is deemed important whilst building teams. Many individual researchers have researched the role of personality in software teams, such as Karn et al (2005), Russell et al (1994), Feldt et al. (2010), Buchanan et al., (2005) etc. By personality, the framework means the factors such as the MBTI (Futrell, 2002) personality type of individuals and the TrueColor (Lowry, 1989) of individuals and other related factors. |
| **Task work Skills** |
| Software Development Process skills: Umphress (2002) notes that skills in properly using software development processes is of immense importance because these skills helps students in the following ways. Firstly, the software development processes highlights the responsibilities of each student which can be infer from what a process describes i.e. the life-cycle activities, the sequence of these activities and their starting and stopping conditions. Secondly, skills in using software development processes makes a student more responsible because these processes makes the internal working of projects more visible to the mentors or teachers. Thirdly, software processes provides the knowledge base (in the form of documentation) that can be used in the future even in academic projects of others. Even in the observation of the authors, the students with good knowledge of software processes normally finishes their projects on time. |
| Software Project Management Skills: All engineers require project management skills to maintain various aspects of a project-driven technological organization no matter how big or small it is (Chard et al, 2009). Software project management skills in this framework means the practical knowledge of usage and applications of all generic phases of project management and the command on tools that assist in managing the projects. The authors of this current research has observed in another research that Software Project Management skills are highly important for pursuing final year software engineering projects successfully (Shaikh et al, 2016). Research has shown that implementing effective project management techniques adds substantial value to temporary or permanent organizations. |
| Taskwork Expertise: By taskwork expertise the paper means the quantified as well as qualitative metrics measuring those skills that are desired in undertaking software engineering projects (for example, GPA, verbal and technical communication expertise etc.) Astonishingly in the literature there are instances where researchers have rejected to recognize taskwork expertise as an important KSAO factor (for example, Stevens et al, 1994, in their own words they wrote: "This study does not focus on the technical KSAs required by the jobs" p. 2). Many teamwork episodes result in failure because of the complications met during taskwork activities (Robillard et al, 2012). There is strong relationship between taskwork and teamwork in software engineering (Robillard et al, 2012), and improved taskwork results in improved teamwork. Same is true for small, medium and large projects including the capstone projects. |
| Work Analysis & Reflection skills: Work analysis is the analysis of the work domain (system) and it precedes a task analysis (Brigit, 2010). An individual having work analysis skills is well-versed in using tools that may be used in a work domain analysis including the decision ladder, the use of abstraction hierarchies, etc. Reflection is a related concept and it is the ability to learn from experiences (Dewey, 1933). |

## 4. IMPLICATION OF KSAO FRAMEWORK FOR COMPUTER SCIENCE CAPSTONE STUDENT PROJECT TEAMS

The identification of KSAO framework for capstone project student teams is relevant to the member selection process. Several researchers have advocated that factors delineated in various KSAO frameworks are useful for team member selection, placement, and their training (Cannon-Bowers *et al.,* 1995; Stevens *et al*, 1994). A team may consist of all individuals having capabilities in all the factors mentioned in the framework.

The teams may also consist of individuals, some of which may possess abilities in some of the factors mentioned in the framework and others may have expertise in other factors from this framework. In a way, the members may be complementing each other by bringing those capabilities that others may not have.

Besides the usage in selection of team members, the framework is also an enabler for a more directed performance appraisal (Marks *et al*, 2001). In the absence of one such framework for computer science student teams, teachers are very much independent in selecting any factors to assess a student on. This liberty introduces biases in student appraisal because the factors selected for one student may be different from the factors selected for another student. A framework proposed in this research will give teachers specific factors to choose from when assessing and appraising student performance. Various KSAOs factors of this framework are related to the aspects of socialization, technical expertise, and management of project and learning from experiences as well.

## 5. CONCLUSIONS

In our knowledge, this framework is the first and so far only KSAO framework designed from the help of literature on student teams. It is pertinent to mention here that the framework proposed in this research is developed to conduct the doctoral thesis of the first author. Under the guidance of this framework, specific second-order factors or team building criterions are identified. Moreover, a software is developed that enables students to form groups based on the criterions identified under the guidance of this framework. The identification of these second-order factors and the software developed is not a subject of this current paper.

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