Taxonomy of Teams, Team Tasks, and Tutors

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Introduction

While significant research has been done on teams and teaming (Salas, et al. 2004), less work has been done to characterize teams and team tasks in terms of the feasibility for them to benefit from intelligent tutoring. This theoretical paper begins to describe how the parameters of team structures addressed may affect the ways in which a team can accommodate external guidance. In addition, parameters of team tasks and resulting team tutors are also described. Examples of both team structures and team tasks are provided so that the resulting theoretical framework offers guidance for design decisions during the construction of intelligent tutoring systems (ITSs) for teams and the Generalized Intelligent Framework for Tutoring’s (GIFT) supporting team architecture.

ITSs have been successful at improving performance in a wide variety of domains ranging from academic topics such as math (e.g., Koedinger, Anderson, Hadley & Mark, 1997) to work-based tasks such as management of power plants (Faria, Silva, Vale & Marques, 2009). However, there have been few ITSs designed for educating or training teams (Sottilare, Holden, Brawner & Goldberg, 2011). Despite much research on teaming since the 1970s, team performance is widely variable and difficult to predict (Sims & Salas, 2007), and there is a significant need for team-based ITSs. A taxonomy of team tutoring is presented (see Figure 29 for top level key elements). This paper describes three taxonomies: teams, team tasks, and relevant tutoring factors. The taxonomies are based on reviewing the teaming literature with a particular focus on the characteristics of each that would influence the design of a team-based intelligent tutoring system. This work leverages the extensive literature review of teaming by Burke et al. (in progress) as well as recent work that has sought to identify those major factors which impact team performance Salas, Shuffler, Thayer, Bedwell & Lazzara (in press).

The taxonomies provided below are designed to help guide the design of software architecture to support team ITSs within GIFT. GIFT is a powerful software architecture designed to support a wide spectrum of intelligent tutoring. It supports the traditional components of most ITSs: the learner model, the domain model, the pedagogical model, and the learner interface, but does so generically (Sottilare, Brawner, Goldberg & Holden, 2012; Sottilare, Graesser, Hu & Holden, 2013). Thus, a multitude of learners might manipulate a wide range of user interfaces as they engage with various domains while being taught using...
a variety of pedagogies. However, the GIFT architecture does not naturally support teams. Team components are necessary if GIFT is to support team tutoring, but they are not present in the current release. In their 2011 paper, Sottilare et al., the creators of GIFT, describe the challenges of creating team tutors in detail.

**Team Tutor Taxonomy**

The three key elements of the taxonomy are described below, followed by examples and implications for the GIFT architecture. The first key element in the taxonomy is based on team characteristics. This element of the taxonomy notes the factors that can vary within teams that would have an impact on the design of a team tutor. The second key element in the taxonomy is based on the characteristics of team tasks. The final key element in the taxonomy focuses on team tutors itself, and the potential features that must be considered.

**Teams**

Characteristics of teams and team members that are important to consider when designing a team tutor can be seen in the taxonomy in Figure 2. Parameters of team structures such as leadership (e.g., vertical, shared, mixed, leaderless, and confederate), organization, communication styles, and location (e.g., co-located or distributed, asynchronous or not) affect the ways in which a team can accommodate external guidance such as tutoring feedback. The leadership structure of a group varies. For instance, there may be a shared responsibility, or the team may use a leaderless structure in which members are accountable primarily for their own roles and/or responsibilities. The organization of a team can dictate collaboration as well. Communication styles can determine how groups coordinate responsibility and facilitate collaboration, which eventually affects performance.

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**Figure 30. Characteristics of teams and team member characteristics.**
When assessing teams, it is also important to consider the team’s purpose as well as the members’ roles (Salas et al. 2004, Sottilare et al. 2011). Different teams have unique rosters including special roles as well as varying levels of expertise. For example, when comparing an infantry squad with a combat engineer squad, both consist of team members who have a contribution appropriate to the squad’s purpose or overall goals. An infantry squad will be better trained to handle a fire fight while the combat engineers would be the preferred choice to construct bridging for heavy vehicles over rough terrain. Team skills are parameters of teams that further support the team’s purpose. Differing from roles, skill division refers to the distribution of competencies possessed by team members that they can apply towards goal completion. These competencies may relate to the task or to teaming itself. Within teams there can also be varying levels of familiarity. How long the team members have been working together can influence a team’s success. Finally, within a team there may exist a learning culture in which individuals contribute their knowledge to other members of the team as the task requires, which ultimately makes the team more effective.

In the creation of a team intelligent tutor, it is critical to consider these team variables. A tutor designed for highly vertical leadership structure, for example, would likely offer differentiated feedback for members at different levels. For a leaderless team, the feedback would have to be structured more for peers. In general, the timing, structure, and level at which feedback is given (to the individual vs. the whole team) may differ based on the characteristics described in the taxonomy as well as on the team’s current developmental trajectory.

When appreciate the implications for the GIFT architecture, consider the above team taxonomy with the only the elements that is relevant to individual tutors: the skills. Structure is not relevant without the other team members, and the subcomponents of skills are also not relevant (e.g., level of familiarity). This significant difference in the complexity of the taxonomy means that GIFT must be able to maintain the state of many more elements of a training mission: skill state for each team member, skill state of the team as a unit, and all the parameters of the team structure. This more complex set of information can be then used to make decisions such as giving feedback to individuals vs. to the whole team.

**Tasks**

The taxonomy of task characteristics in Figure 31 is again an initial attempt to establish a checklist of key factors that must be considered in the design of a team-based ITS. Tasks are the activities teams perform. In the context of this research, the tasks would be performed within a training environment with the purpose of providing a detailed assessment. The task at hand has a strong influence on how an intelligent tutor is designed, and with team tasks, the numerous roles and relationships between members’ tasks can make the tutor design much more complex than the sum of analogous tutors for individuals. Factors that influence tasks as a whole are solutions, task interdependence, routine, complexity, time constraints, information exchange, environmental fidelity and task type (Figure 2). Solutions refers to how tasks are negotiated and solved. There may be a single solution, multiple solutions, or the task may be open-ended, with no particular solution planned. Training tasks focused on reaching a specific outcome typically have a small number of solutions, while training focused on a process is typically more open-ended. In some tasks designed to teach compromise and negotiation, the scenario may be specifically designed so that there is no solution.
The interdependence of tasks is also a key factor. Task interdependence consists of four types: pooled, sequential, reciprocal, and team interdependence (Saavedra, Earley & VanDyne, 1993). Pooled interdependence occurs when members of a group complete similar tasks mostly independently, such as a team of customer service support agents. With sequential interdependence, members all perform separate but related tasks in a specific order to accomplish a greater goal, e.g., in an assembly line. Members’ tasks depend on the work of previous members. With reciprocal interdependence, members’ tasks mutually depend on each other’s work, and the order is flexible, e.g., the writing of a paper between co-authors. Lastly, team interdependence is the most dynamic structure, in which each member’s tasks and the particular sequence of work are unspecified and are decided within the team.

Furthermore, it is important to characterize the variability of the routine and the task complexity, because both affect the learning curve and overall performance. Tasks become less strenuous or challenging as they become familiar to the learner. For instance, in the process of two people stocking the back room of a coffee shop, the members may at first become overwhelmed with the complexity of the task and figuring out how to work together, but over time the process becomes less complex as the members build a shared mental model of the equipment, the task, and their team members, which allows them to efficiently coordinate. The cognitive load is reduced as the task becomes familiar. A tutor for a team must be able to accommodate these team learning curves.

Time pressure typically occurs as a result of a set time constraint, although time constraints do not always lead to time pressure (Ordonez & Benson, 1997). It can also be caused by a factor of increased workload. The amount of time pressure felt by participants in an exercise may positively or negatively affect the team’s performance, and can at times be an effective motivator (Andrews & Farris, 1972; Stewart, Lam, Betson, Wong & Wong, 1999). Information exchange within the current context is related to team

![Figure 31. Characteristics of team tasks.](image)
communication, but refers to the forms of information that are generated by the systems used within the task, the user interfaces used by the team members, and how easily the information may be shared. Environmental fidelity, in a tutor design context, is the degree to which the team task is conducted in the actual context of practice (e.g., the “field”) as opposed to within a lab or simulation. The necessary degree of fidelity varies according to the skills being trained. The feedback given to a team and its members by a team ITS might not differ in the field vs. in the lab, but the thresholds for feedback activation might vary, since team members in the field might be experiencing a higher levels of stress.

Task types include, but are not limited to, managing, advising, negotiating, performing a service, problem solving, and psychomotor action (Wildman, Thayer, Rosen, Salas, Mathieu & Rayne, 2012). Managing tasks involves directing, supervising, or overseeing the work of others in an authoritative role for the specific purpose of achieving a goal despite given conditions. Meanwhile, advising refers to providing means to solve a problem remotely via professional support through expert assistance in a consultative role where the advisor does not have managerial. A service task is a social interaction in which another individual or group. Negotiating involves coming to a compromise or successfully overcoming differences. Psychomotor action is the operation of a product, machine, or object. Problem solving can refer to solving ill-defined or novel problems.

One implication of this task taxonomy for GIFT is the needed support for a wide variety of methods of monitoring individual and team performance—not only the typical individual performance with a system but also the communications between team members, and the actions of the team as well as actions of individuals. Also, whenever a team is at work on a task, there is the metatask of performing well as a team. GIFT will need to support these parallel tasks simultaneously. For example, it’s possible that a task is being accomplished well, but the team members doing it don’t trust each other and are not collaborating well. GIFT will need to be able to tutor on both the task work and the teamwork.

**Team Tutor Structure**

Once the team structure is defined and the task is chosen, the team tutor can be initiated. However, there remain a number of choices in tutor design. This section describes a taxonomy (Figure 32) of the variables that characterize team tutors in particular. Tutors are broken down into categories consisting of feedback, pedagogy, adaptivity, environmental context, and evaluation. The subcategories of these variables are not intended to be exhaustive; there are additional options under each, but these categories offer a list of decisions that must be made during tutor design.
Figure 32. Characteristics of team tutors.

The pedagogical decision includes options such as apprenticeship scaffolding, in which the tutor guides the learner to mastery in a series of successive approximations with less and less scaffolding. A Socratic dialogue, on the other hand, would promote reflection by the learner in a series of questions and answers. Both of these are common approaches in existing one-on-one ITSs, but are complicated when tutoring a team. Performing Socratic dialogue at a team level requires interrupting the team (e.g., event-based training (Fowlkes, Dwyer, Oser & Salas, 1998)), waiting until the task is complete and doing an after action review (AAR), or offering the team advice when the team decides on its own to pause and consult the tutor.

Feedback is also an important element of tutoring. Individuals are motivated upon receiving feedback as it informs them of their progress and directing the learner towards a desired behavior. In terms of timing, real-time feedback provides the learner instruction without delay and avoids the development of inaccurate cognitive structures, behaviors, and attitudes that could be difficult to mitigate later. A primary challenge with this approach is that it may interrupt action or team communication, adding to members’ cognitive load. Thus, after AARs are favorable when evaluating learner’s progress through the entire task scenario. The tutor may observe the team’s performance without interfering with the task. Feedback modality can also vary, and must be considered based on the cognitive loading of the tasks. If the learners have visual tasks, for example, feedback should probably arrive in a different modality such as audio. If team members are moving during the task, strong vibrotactile feedback might be useful. See the companion paper in this volume (Walton et al., 2014) for a further look into feedback for team tutoring.
The adaptability of the tutor is also a design decision. A simple tutor will contain mainly a set of static feedback responses that are triggered by behavioral predicate rules: If the learner does X, display feedback Y. A more complex tutor will make the conditional of that rule more complex, changing the feedback depending on the learner’s history and accumulated skills, e.g., “If the learner does X, and has low skill ratings on skills A, B, or C, then display feedback Y.” A yet more complex adaptive approach is changing the consequent of the rule, changing the feedback itself based on learner behavior or conditions within the training environment, e.g., “If the learner does X, and has a history of other actions A, B, C, then give feedback Y(A, B, C, X).” Finally, the tutor may also adapt to overall team behaviors, which could become inputs to both the conditional and the consequent, e.g., “If 70% of team members do A and B, then give the entire team feedback Y(A, B).” The balance between individual vs. team feedback depends on many of the characteristics described above. DeShon, Kozlowski, Schmidt, Milner, and Wiechmann (2004) offer a brief overview of this issue.

The tutor may vary based on environmental context. In the field, the tutor must consider a broader variety of states within the training scenarios; it may not have specific feedback for all possible actions. In the lab, or an embedded context (a simulated training scenario is embedded within a more realistic setting in the field), the tutor authors have more control over the scenario and its possible states, and can build a more exhaustive tutor.

Finally, the evaluation approach of a team tutor may vary significantly based on the task and the learning goals. However, the mechanics of the evaluation affect the design of the tutor. For example, if performance evaluation is based on direct, accurately measurable actions by learners, the evaluation is simpler than if the learner’s performance must be inferred from a variety of indirect cues, such as biometrics.

The implications for GIFT are significant. Most notably, GIFT must be able to consult multiple individual learner models and a team learning model when choosing its next pedagogical action. Also, GIFT must be able to support the increased complexity of scoring rules that 1) take multiple individuals’ states into account, and 2) take team roles into account, e.g., “If the pilot-learner has done X and said Y to the co-pilot-learner, but not said Z to the crew-learners, and the co-pilot-learner has done A but not B, then give feedback F1 to the pilot-learner, F2 to the co-pilot-learner, and F3 to all learners.”

### Examples

#### Advanced Embedded Training System

An example of a team tutoring in practice is the Advanced Embedded Training System (AETS). AETS is an ITS focused on improving training and reducing manpower usage within shipboard simulation training (Zachary et al., 1999). While effective, it does not replace the role of a human instructor, but rather makes the workload lighter for an instructor through the use of multiple feedback components. The AETS focuses primarily on the Air Defense Team, which is considered one of the most important groups within a ship’s Combat Information Center: that team focuses on representations of airborne objects around the ship and differentiates threats from friendly entities.
AETS touches on several points contained within the taxonomies. The use of an experienced team with a distributed skillset is identified in the team taxonomy. There is a shared responsibility as each member plays their role on the team, which is co-located in a real-world environment setting. The apprenticeship pedagogical style is used, since the team is monitored by a human instructor who uses a defined problem-solving method. Due to this intensity of the work task, real-time feedback was a detriment to task attention and AAR was chosen.

**Jigsaw II**

While not an ITS, Jigsaw II is a team learning technique that heightens a student’s sense of responsibility for learning by making each team member an expert for a particular portion of an instructional unit (Slavin, 1978). In using that sense of responsibility, the concept of team maintenance is applied to this activity. Each student is responsible for mastering a segment, and then teaching that segment to the rest of their team.

The activity begins when each student is assigned a chapter to read and given what is called an “expert sheet” with necessary benchmarks to meet. This can be seen as role definition within our taxonomy of teams. Once the material is reviewed, member from various teams who studied the same portion meet to compare notes on their topics for a period of 30 minutes. After this session, each expert returns to their respective teams and then teaches their subject while learning their compatriots’ designated subjects. Finally, the team takes a quiz on all of the subjects. This is a form of evaluation, with the team score as a form of AAR. A key feature of this task is reciprocal interdependence (see task taxonomy) as each member depends on his or her teammates to provide the information needed to succeed.

**Hidden Profile Task**

This classic well-studied problem-solving task (Lu, Yuan & McLeod, 2012; Stasser & Titus, 1985) gives a small group the role of a hiring committee and distributes information about candidates to each member. However, the information varies by team member and is designed to mislead each team member about the best candidate. Only by pooling their information can the group make the best decision as a team. The leadership structure (see team taxonomy) may vary, being leaderless in some groups or with a specifically defined group leader in others. Task actions are mainly discussion, though they are based on a number of written documents. It can be easily done with co-located or distributed teams. An effective team is able to share all needed information with each other, and this is typically difficult (see communication in team taxonomy).

**Small Group Survival Scenario**

This classic small group problem-solving task, typically based on variations of the NASA Moon Survival scenario (Hall, Mouton & Blake, 1963), the Winter Survival Scenario (Johnson & Johnson, 1975), assigns the challenge of planning for survival by prioritizing the importance of 20–30 items. Task actions are mainly discussion, and therefore can be easily done with co-located or distributed teams. An effective team is able to elicit ideas from all members and come to consensus on a plan. To measure individual performance, the individual’s contribution is assessed. This can be done by recording the number of ideas initiated by an individual as well as affirmation of teammates. In this task, there is a correct solution,
though the process is also key to the learning. For the session to be an effective learning experience, participants must reflect on their behaviors, so a Socratic pedagogy, accompanied by video or audio replays of what happened, is effective.

**Conclusion**

These team, task, and team tutor taxonomies can be used to identify the variables that must be considered when designing ITSs for teams. Similarly, they can also be used to guide functional requirements for software like GIFT, so that it may support a large variety of team tutoring experiences. Identification of the key elements in a team tutor can be used to inform the GIFT development roadmap. The biggest impact is that GIFT should be able to consult multiple learner models when choosing its next pedagogical action. For users of GIFT, this addition will translate to an increase in the expressiveness of the tutor. In addition, our taxonomies may be used individually to compare other tutors by placing their characteristics within the taxonomies. Future work will include the expansion of these taxonomies and validation of them through the development of actual team tutors.

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