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Developing future translational scientists through authentic learning and assessments

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Abstract

The Interprofessional Research Design course uses authentic learning pedagogy to bring together students from different education tracks (PhD, MD, MD/PhD training) to engage in interprofessional collaborative skills toward completion of a capstone project, a National Health Institutes (NIH) R21-style grant proposal. The course, underpinned by principles of team science, begins with a leadership training workshop to introduce students to effective leadership and teamwork strategies for interprofessional team environments. We used several assessments during the course to monitor leadership and team dynamics. We analyzed three assessments (leadership self-efficacy testing, iterative team contracts and reflective essays) to better understand students' learning experiences. Self-efficacy testing was administered before leadership training (pre) and at the end of the course (post-then); scores were analyzed using a repeated repeated measures ANOVA. Iterative team contracts were analyzed qualitatively using both deductive and descriptive methods. Reflective essays were analyzed using a general inductive approach. Nine teams of 32 students (23 MD; 9 PhD) participated in the class over 2017–2018. Self-efficacy testing

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Declaration of Competing Interest

None.

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using post-then timing to control for response shift showed a statistically significant increase in self-efficacy across all measures. Deductive qualitative analysis of iterative contracting showed evidence of team processes which support successful team performance; and descriptive analysis mapped productive behaviors. In reflective essays, seven of the nine teams collectively described their experiences positively; e.g., themes included empathizing with group members, sophisticated communication and collaborative workflow/styles. For negative experiences, themes were related to basic communication, poor integration and the theory-practice gap of leadership training. These findings demonstrate the usefulness of an authentic learning pedagogy focused on teaching the practice of team science.

Keywords

interprofessional education; team science; translational science; leadership; communication; medical students; graduate students

1. Introduction

The Institute for Translational Science at our organization utilizes Multidisciplinary Translational Teams (MTT) to undertake biomedical research focused in a variety of areas (Calhoun et al., 2013). Researchers from multiple disciplines (e.g., bench scientists, clinicians, informaticians, ethicists, biostatisticians, trainees, and others) work together; for some team members, the MTT is the first time they have worked collaboratively with multiple experts outside of their own field. Based on this work, we believed that timely introduction of the principles of Team Science should be offered to students interested in translational research early in their learning to promote better leadership and interprofessional teamwork in translational research environments.

Since 2012, we have offered a seven-week Interprofessional Research Design Course (Kane & Balstes, 1998), which brings together students from different disciplines (science and medicine) and educational tracks (PhD and MD) to learn interprofessional collaborative skills and leadership styles that support success in translational research environments.

We use authentic learning pedagogy which dictates the use of real-world tasks and the simulation of real-world environments and interactions (Edelson, 1998; Herrington et al., 2014) for both learning and assessment. Students work in teams of three or four students to write an National Institutes of Health (NIH) R-21 style grant proposal as the final capstone project. In 2017, we introduced a leadership training course (Chao et al., 2018) and instituted the use of team contracts, so that each team can develop a mutually agreed upon framework for working together. The course elements (Table 1) map to specific core competencies in our graduate program as well as Team Science Competencies (Table 2) (Wooten et al., 2019).

To assess the effect of our course design on attitudes, social and professional interactions that characterize the practice of team science as an individual and as a team in the classroom setting, here, we analyzed team dynamics and report our findings on the use

of team contracts (2018 only), reflective essays (2017–18), and the results of a self-efficacy instrument evaluating leadership training (2018).

2. Methods

Course:

This report has a retrospective mixed-methods research design and was approved by the UTMB Institution Review Board (18–0143). Authentic learning practices utilized in the Interprofessional Research Design Course were mapped to both graduate school competencies as well as team science competencies. Students were tasked with completing a NIH grant document including key components of topic selection, specific aims, experimental plans with expected outcomes and alternative approaches, and explaining their ethical approach to their human subjects or animal subjects. Other examples of authentic practices include topic selection, task setting, and expert interactions (e.g., consultation with a biostatistician). Students were assigned to their teams; assignments parallel an authentic experience since in real-life, team members do not often select each other. There were five course assessments: the written proposal itself, presentations, team contracts, self-efficacy testing and the reflective essay. The first three are assessments which mirror authentic practice (Svinicki, 2004) and the last two are reflective in nature supporting student metacognition about their learning by helping students recognize their development and self-evaluate. Formative feedback is provided to students throughout the course upon completion of tasks. Assessments are pass/fail, given the focus of this course is introducing students to new concepts and ways of understanding themselves, their leadership styles, how to interact within teams in the real world context of learning about grant writing and translational science, and interacting with experts in the field.

We reviewed selected deliverables from the 2017 class ($n = 17$) and the 2018 class ($n = 15$) of students. For the mixed-method study design, the three types of data included: 1) team contracts which represented artifacts of the team work and authentic learning tasks; 2) the Kane-Baltes Leadership Self Efficacy test (Kane & Balstes, 1998), which assessed the student's self-perceived benefit of leadership training on their team intereactions comparing a pre-post-then testing method (Mezoff, 1981), and 3) end-of-course reflective essays, which were qualitatively analyzed to explore learner's individual experiences.

Team Contracts:

Each team was required to submit a Team Contract iteratively over four time points (Weeks 2, 3, 5 and 7). Each team documented explicit expectations or practices determined as a group with regards to collaboration, conflict management, monitoring individual and team performance, and creating a positive team environment. The document listed the tasks that each team member had committed to with an expected completion date; refinements or changes were evident in successive versions. We performed a two-step analysis in order to understand whether the contracts were fulfilling their intended purpose: 1) we used the team process taxonomy outlined by Marks et al (Marks et al., 2001) to deductively analyze contracts within each team; and 2) we undertook a descriptive analysis of contracts documenting team behaviors that showed explicit discussion around

roles, responsibilities, expectations, professionalism and performance. Each analysis is independent but complementary. In 2017, teams submitted only one contract; here, we only analyzed the 2018 cohort because we instituted the iterative contracting for the first time.

Kane-Baltes Leadership Self Efficacy test:

Students took the test before (pre-) completing a 1.5 day leadership training workshop at the beginning of the Interprofessional Research Design course, and again after course completion (post-then). Students were asked to rank their agreement with each of the eight statements on a 1–100 scale from “Strongly disagree ” to “Strongly agree ”. Test answers comparing all three (pre-post-then) were analyzed using the repeated one-way repeated measures ANOVA; we also analyzed the data by comparing pre-post only and post-then only. A $p \leq 0.05$ was considered significant for all analyses. Sphericity conditions were met for all eight questions. If differences were found, the Benjamini-Hochberg post-hoc test was used to correct for multiple hypothesis testing (R v3.5) (“R Core Team. R: A language and environment for statistical computing”, 2018). To analyze all eight questions together, a two-way repeated measures ANOVA was used with time and question as the within-group variables. Sphericity conditions were not met for the question variable, so the Greenhouse-Geisser epsilon correction was used. For all analyses, there were no significant interaction effects.

Reflective Essays:

Reflective writing aims to make the writer understand both themselves and the situation about which they are writing through a process that encourages critical self-awareness (Levine et al., 2008). Reflective essays are a rich source of data, as they provide student narratives of their experience. We performed a qualitative analysis of essays from the 2017 and 2018 cohorts to understand student development and avenues for course improvement, through a better understanding of the student experience.

Essays were de-identified by one of the course faculty (CC). Teams were assigned numbers (e.g.,Team 1) and individual students were assigned their team number and a letter (e.g,. Student 1-A). We used a general inductive approach (Thomas, 2006) in order to explore the student experience without pre-conception about what it might be or what course development might be needed. Another author (ET) reviewed each de-identified essay and coded the data openly using QSR NVivo® Version 10; codes were determined *post-hoc* and were refined and rationalized before organizing them into draft themes informed by the research objectives and literature. ET is not core teaching faculty on the course and, therefore, does not know the students. She is a bioethicist and health researcher who has experience undertaking qualitative research in various settings. Draft themes were then discussed among team members over three rounds before further refinement and final confirmation of the themes. Each theme was further mapped to relevant Team Science competencies as evidence of authentic learning design achieving desired outcomes.

We had 32 reflective essays across nine teams as source texts. We coded themes as “positive”, “negative” or “neutral” in characterizing the statements written by the students. Since “Neutral” themes (i.e., descriptive data of a situation, task, or their learning) lacked

relevance to our overall objectives and neutral themes did not impact course development nor describe student development, we focused solely on the positive and negative themes. Data saturation was reached in the analysis of the 32 source texts.

3. Results

Each team consisted of one PhD or MD-PhD student (representing the biomedical scientist), and either two or three medical students (representing the clinician or clinician-scientist). We had five teams in 2017 and four teams in 2018, totaling 32 students.

Team Contracts:

We analyzed the contracts of four teams (2018 cohort), totaling 16 contracts. On average, team contracts were four pages long (range: 1–7; total 88 pages). The contents varied greatly between teams. Some teams set comprehensive rules, task plans, reflections, deadlines and conflict management plans, while others took a minimalist approach. Some teams decorated contracts with photos and included humor. Overall, the contracts were very diverse and specific to each team, but provided a source of artifacts of the learning experience.

For the deductive analysis, each team's contracts were reviewed for evidence of the three processes at the high-order level: 1) transitional processes, 2) action processes, and 3) interpersonal process (Marks et al., 2001). In this analysis, it was sufficient for teams to have completed a process over the course of all four contracts rather than in each individual contract, acknowledging that the processes occurred differently over the time span of a project. We found that evidence of all three team processes were present in Teams 1 and 4, with Team 2 failing to document their interpersonal processes, and Team 3 failing to document both their transition and action processes.

For the descriptive analysis, we extracted five desirable team behaviors from review of the contracts: rule specification, role specification, task identification, workload distribution and reflection (Figure 1). These behaviors support explicit discussion around team dynamics, expectations, responsibilities and performance (Klein et al., 2009). Team 1, 2, and 4 completed four out of five behaviors at all four timepoints. Team 3 only completed three behaviors at all four timepoints.

Kane-Baltes Leadership Self Efficacy Test:

The Leadership Self Efficacy test (Kane & Balstes, 1998) assessed the student's self-perceived level of leadership skills. The pre-post comparisons shows significant differences for six of the eight statements; however, comparisons of post-then results demonstrate significant differences in scores across all eight statements (Table 2). To better visually understand the relationship between time and question, Figure 2 shows an interaction plot between the three time points (pre, post, and then) as well as the eight statements being asked of each student at each time. The *then* response had the lowest overall response values (Figure 2). These results show that post-then comparisons may be more representative of the positive impact of leadership training, rather than a pre-post comparison.

Reflective Essays:

Seven of the nine teams collectively described their experiences as largely positive. Themes relating to positive team experiences were *empathizing with group members, sophisticated communication* and *collaborative workflow/styles*. In Table 3, we also mapped the themes to our Team Science competencies (Wooten et al., 2019) in order to highlight how our findings support the use of authenic learning pedagogy in the course. We found that those who had a positive experience utilized knowledge and skills learned during leadership training to better understand and communicate with their teammates leading to a more collaborative and dynamic workflow. These groups had higher degrees of communication both between their task assignments and within task completion periods. Evaluating the contracts from 2018 in concert with the essays from 2018, we found that essays documented processes and behaviors in the contracts, providing a further source of triangulation. These teams also showed more awareness of others' needs in work and communication styles. We describe each of these themes in more detail below with example quotes in Table 3.

Empathic team interactions—Teams that reflected on their experience positively described trying to understand their various team members' needs and adjusting their actions to meet those needs. This was related to empathizing professionally (i.e., trying to understand a person's knowledge or workstyle) as well as emotionally (trying to understand someone's vulnerabilities within the team dynamic). The leadership training workshop at the beginning of the course promoted these self-assessments by having students openly discuss their personalities, communications styles and needs, as well as discussing the differences that arise from different disciplinary backgrounds.

Open and proactive communication—Team members who relayed positive experiences discussed communication practices that showed a greater degree of sophistication. Communication styles were open and proactive; various members described adjusting their discipline-specific jargon or communication style to the group level. Overall, teams communicated more frequently both within a task (while writing a grant section, for example) and between tasks (when not together or actively collaborating).

Teams described being proactive about their collaboration and the communication that would support this behavior. They also appeared to be better at giving and receiving feedback and helping each other become better, mapping to the interpersonal processes specified by Marks et al (Marks et al., 2001).

Collaborative workflow—Positive team experiences reflected greater collaboration and support of members when completing work. Some groups adopted online tools (e.g., Google-docs) to facilitate real-time collaboration on documents, or supported different members to learn new things, there was evidence of greater teamwork overall. There was also evidence of a shared leadership model (Engel Small & Rentsch, 2010) in some groups, something that the course actively encourages. While it is important to have clear roles and teams are encouraged to assign a project manager, decision-making and overall leadership are meant to be collaborative. For some teams this seemed to work; for others this was difficult, as is shown in the negative themes.

For those that had a negative experience, themes were related to *basic communication, poor integration* and the *theory-practice gap of leadership training* (Table 4). Students who struggled showed much less in- and between-task communication and were unable to address the personal needs of other members in communication and workflow (while still often being able to identify them).

Basic communication—Teams that had negative experiences showed both less sophisticated communication and less frequent communication. Communication largely occurred in scheduled meetings and members made little or no effort to speak about communication styles, informational needs, or address conflict when it arose. When teams only communicate at set meetings and fail to follow-up with each other in between, this can lead to greater conflicts at pre-set meetings. Conflict that these teams were unable to manage well. For example, if one member fails to meet their obligations the entire team had issues at the next meeting timepoint. In contrast to the positive themes, with more communication, when individual students fell behind, this was identified early in between-meeting communications and the team rallied around to support the individual in completing their task, which is only possible with open and frequent communication.

Poor integration—Teams with negative experiences also showed a lesser degree of collaboration or teamwork overall. Teams operated as a group of individuals doing a set of tasks in isolation that they then collated as needed. Students who had a negative experience isolated themselves or felt left out. In part, integration relates to their communication style, but also seems to reflect the opposite experience of the teams having positive experiences. That is, team members failed to consider their peers' perspectives, experiences, knowledge or feelings. A lack of empathic activity, along with basic communication, led to overall poor integration.

Theory-practice gap of leadership training—Team members reporting negative experiences frequently were able to identify what they should have done, even when they failed to do it. While some learned from it (those who overall had a positive experience), others failed to do so (those having an overall negative experience). The data showed some degree of retention from the workshop training, but an inability to realize those actions in practice. Students with negative experiences frequently described avoiding communication in order to avoid conflict, failing to realize that "avoiding communication" exacerbates conflict.

Overall negative experiences seemed to be attributable to teams failing to communicate and integrate with their peers despite being provided with some knowledge and tools during leadership training, to help them learn how to relate with members who may have differing personalities, communication styles, informational needs or work processes.

4. Discussion

The study of Team Science is the investigation of characteristics which define effective teams and the development of various interventions, tools, and metrics to support and evaluate teamwork. (Barczak et al., 2010; Hall et al., 2018; Wooten et al., 2014). Early

reviews of the team science field (Borner et al., 2010; Fiore, 2008; Stokols et al., 2008) articulated both promise and problems; several thought leaders stated the need for training programs and curricula (Begg et al., 2014; Jackson et al., 2010; Wildman & Bedwell, 2013). A recent review (Hall et al., 2018) found only two empirical studies evaluating team science education; one explored attitudes and products from undergraduate courses (Misra et al., 2009), and another reported on reaction toward coursework, perceived course effectiveness, learning scientific skills, and trainees' attitudes toward research (Vogel et al., 2012). Other studies have focused upon early career scientists' confidence in team science collaboration as a result of formalized training (Read et al., 2016). The Interprofessional Research Design Course aims to use an authentic learning pedagogy towards the development of Team Science competencies (Wooten et al., 2019). We analyzed three course assessments to gauge the effectiveness of our course on leadership, and teamwork skills: the use of team contracts (one of the authentic team assessments), the Kane-Baltes leadership self-efficacy questions (repeated measures), and individual reflective essays (the reflective assessments).

Team Contracts:

Marks et al (Marks et al., 2001) in their work outlined a number of team processes that act as indicators of potential team success. Student contracts are relatively common across many disciplines (Clinton & Smith, 2009; Kapp, 2009). Students are asked to engage in a conversation with each other at the beginning of a project to help make explicit expectations and a plan for the work ahead. Contracts aim to avoid the common problem reported in team-based projects where teams fail to cohere and individual members become burdened with most of the work while others do little or none (Gatfield, 1999; Pauli et al., 2008; Walker, 2001). Transition, Action and Interpersonal processes as outlined by Marks et al (Marks et al., 2001) describe the interactions in which the teams should be engaged. These processes also align with our Team Science competencies. Groups completing contracts demonstrated competencies such as *Addressing issues and resolving conflicts, Monitoring/debriefing, and Creating change/development plans* (Table 1) (Wooten et al., 2019). By asking students to complete iterative contracting we hoped to prompt and support their engagement in these various processes and related competencies at regular intervals during their learning; however, the contracts do have limitations. The truthfulness and engagement of the students when filling out the contracts is not always clear. Student anonymous feedback provided in the general course evaluations undertaken at the end of all courses in our institution indicated that some felt the contracting was superfluous, or "busy-work". Therefore, the ability to gain true insight into team functioning is potentially limited.

Learning analytics is a burgeoning activity in higher education (Siemens, 2013) with new methods of digital and real-time evaluation and intervention being developed. Iterative contracts offer an opportunity for a learning analytic approach to this course because real-time insight into team functioning allows for intervention when desirable behaviors or team processes appear to be lacking. For example, if Team X fails to document workload distribution at Contract timepoint 2, then faculty could intervene early with something directed to address the cause of the problem. This is in contrast to other team-based project work, where students often report that teams are dysfunctional throughout the whole project and no intervention is provided (Pauli et al., 2008; Walker, 2001). The two qualitiative

analyses we performed, taken together, allow us to triangulate data on team interactions. In both analyses, Team 3 failed to document more processes and behaviors compared with other teams. However, lack of documentation is not a clear indicator of absence of the process, but could serve as a proxy.

As this was an analysis of a small sample, future work is required to allow a greater understanding of team processes and behaviors and their usefulness in helping teams form and succeed within the course. However, our analyses demonstrate that these processes and behaviors can be captured in contracts and that either analysis could serve as a learning analytic tool given their overlap/complementarity.

Kane-Baltes Leadership Self Efficacy Test:

In 2017, we used the Leadership Self Efficacy test (Kane & Balstes, 1998) to assess the student's self-perceived benefit of leadership training by comparing answers obtained prior to the training (pre-test) with their matched answers at the end of the course (post-test). In 2018, we added a "then" test because students may initially mis-estimate their level of self-efficacy depending on their background level of knowledge or experience (Mezoff, 1981; Rohs, 2002). Since students cannot accurately know what they do not know before the leadership training, post-then comparisons attempt to counter this phenomenon by asking students to first rate their perceived self-efficacy at the end of the course (post-test), and then to imagine themselves again at the beginning of the course and rate how they would now judge their self-efficacy before (then) starting the course (Rohs, 2002; Rosch & Schwartz, 2009). Asking students to think back to before the leadership training (how did you feel *then* ?) allows students to use their recent new-found knowledge and experiences to assess their original position before the course.

In 2017, as previously published, pre-post testing for a previous student cohort showed a statistically positive difference for only two of the eight statements (#4 & 5, Table 2) and overall (across all statements) (Chao et al., 2018). However, in 2018, pre-post tests showed statistically significant differences for statements 3, 5, 6, 7, and 8. Pre-post testing showed wide variability between the two cohorts, despite exposure to the same leadership training course. Post-then testing showed significant positive differences across all eight statements and thus provides a more accurate measure of students' self-efficacy after the intervention (leadership training), consistent with the literature (Rohs, 2002). This is important not only in understanding whether the course is having the desired effect on students' self-efficacy working in interdisciplinary teams, but also because in undertaking the exercise, they once again actively engage in a reflective exercise that shows them their progress over the course. This metacogntive learning task is not possible with the pre-post testing where there is a significant gap in time between the reflective exercises.

Reflective Essays:

Reflective writing is a common tool used in medical education to help students become more self-aware and gain insight into their motivations and behaviors (Sandars, 2009). In asking our students to write reflectively at the end of the course, we hope to provide them with space to understand their experience, to acknowledge their growth, what went well,

what did not, and prompt them to explore why things occurred the way they did using their new-found knowledge about people, communication, and conflict. Reflection on the experience of working with their team also exemplifies the practice of critical thinking and metacognition on the team experience, exhibiting two characteristics of authentic learning (Edelson, 1998; Herrington et al., 2014). Our investigation of course artifacts related to these activities and the asessments suggest students gained skills in teamwork and leadership as outcomes of the authentic learning experiences.

In our analysis of the reflective writings, the data showed that open communication styles, collaborative workflows and empathic practices, all of which were encouraged by the leadership training, led to more positive experiences for those able to translate their learning into practice. The positive themes reflect our Team Science competencies (Wooten et al., 2019) (Table 3) with many of the behaviors and actions described by teams.

These findings demonstrate the usefulness of leadership training which facilitates student self-awareness and empathy, as well as effective communication, leading to collaborative high-functioning interprofessional teams. However, we also found that those unable to bridge the theory-practice gap of the training failed to communicate well and empathize; even though they were able to recognize what may have caused conflict, they were unable to address the problem(s) effectively.

5. Limitations

Our data was sourced retrospectively from tasks undertaken as part of the course, and was not independently collected research data. This material has inherent limitations in trying to understand student experiences of a course. Contracts can be completed perfunctorily or inaccurately. In reflective essays, students' degree of insight into their own motivations and behaviors or effects on others may be minimal or lacking. Similarly, students' willingness to share their insights with course faculty may be limited or students'output may reflect what they believe course faculty wish to hear. This will vary student-by-student and so our ability to gauge either the degree of authenticity or openness in any one student's reflection or team contract is not possible. We hope to address this in the future.

5.1. .Future Directions

Based on this work, we are undertaking a number of changes in the course, including:

1. Weekly short reflections with a quantification of workload distribution based on the perception of the individual rather than (solely) team-based quantification. As noted above, limitations of the contracts and reflective writing are the truthfulness and engagement with the tasks. Weekly short reflections serve both pedagogical (Etkina & Andre Harper, 2002) and learning analytic aims. By reflecting weekly, we hope students will identify their learning and positive experiences explicitly as they go, improving their self-confidence; or be able to identify and address issues early. The short weekly reflections may provide us with insight into the difference between team-based reporting of workload (team contract) versus individual-based reporting of workload, which will help

us decide the usefulness of either element for pedagogical and for learning analytic purposes.

2. Real-time academic coaching. We plan to introduce real-time academic coaching to address the theory-practice gap noted in our analysis of reflective essays. Professional coaching (Thorn & Raj, 2012) will provide our students with an academic coach who will meet with them and focus on their team dynamics, communication, and project management. This coaching will further support the development of TeamScience competencies (Wooten et al., 2019) by encouraging appropriate behaviours and supporting the development of communication skills that underpin many of the competencies. For example, guidance working through a conflict in a controlled environment can help students implement tools used in the workshop and see its effect on outcome (addressing the theory-practice gap).

6. Conclusion

Leadership training considering Team Science competencies can be incorporated into multi-disclinpinary translational science education programs with positive effects and can be evaluated using course artefacts. Further work to explore possible supportive interventions throughtout a program may be necessary to ensure all students can apply their learning in practice.

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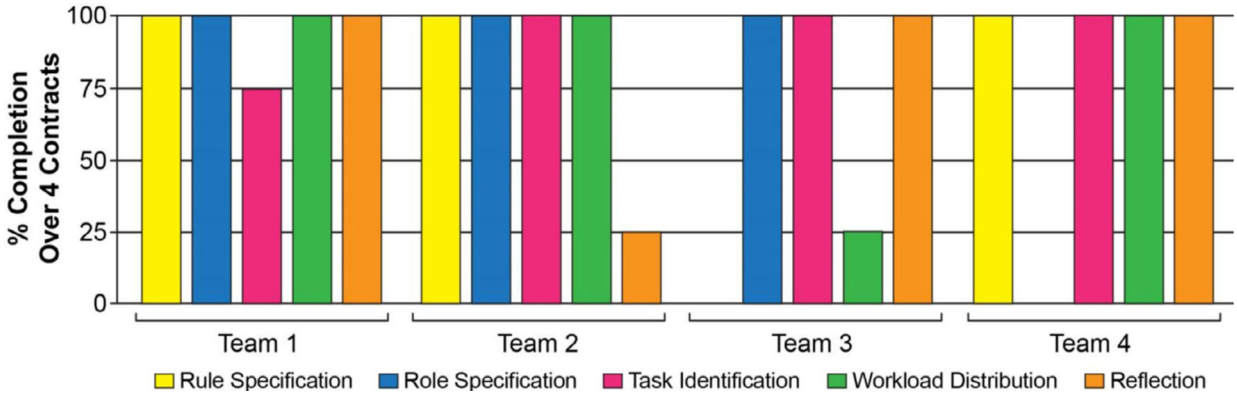

Figure 1.

Behavior mapping across 2018 team contracts. Documentation of behavior was noted at each timepoint for each team in order to understand consistency of desirable behaviors across the duration of the course. Therefore, 100% means that a given behavior was documented in all four contracts, whereas 25% would indicate documentation in only one of the four contracts.

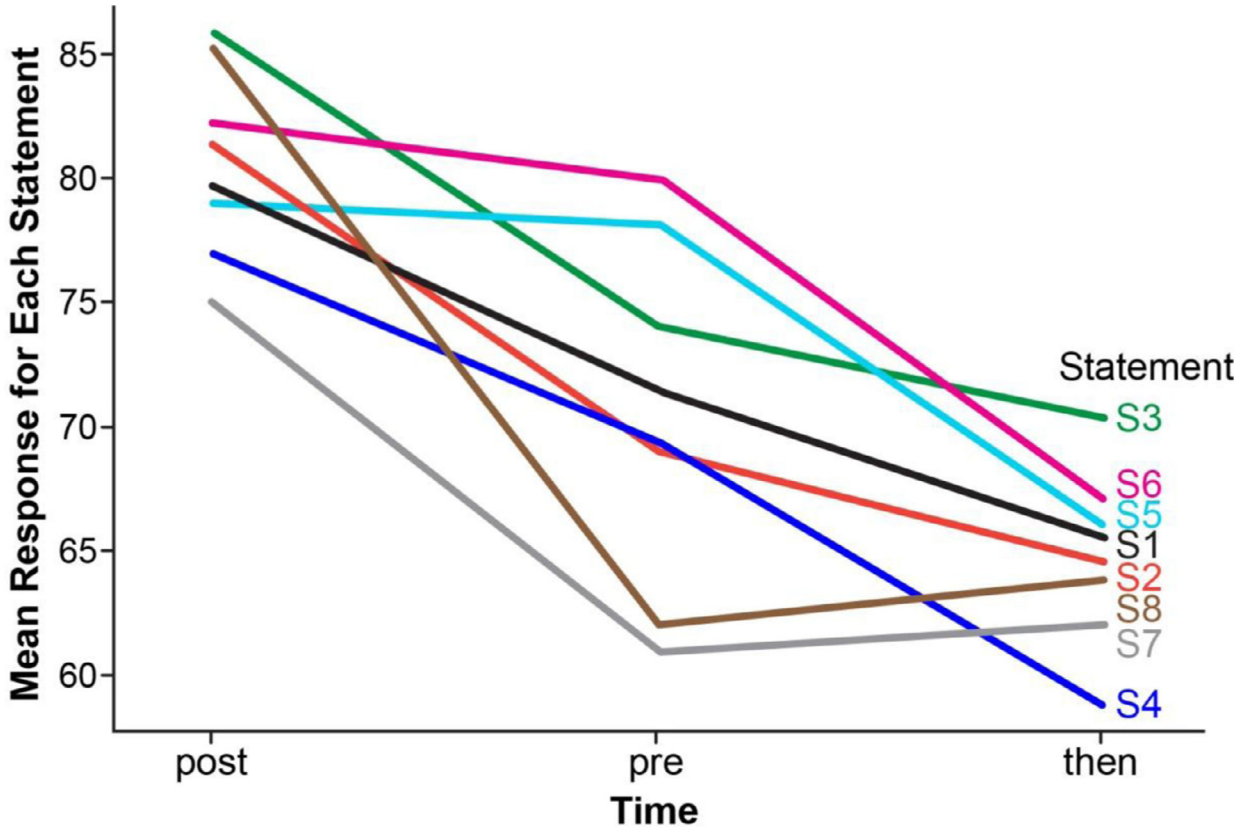

Figure 2.
Interaction plot between time (Pre, Post, Then) and question (Statement) showing average response values for each question at each time point.

Table 1

Course Elements and Description.

Course Element	Description
1 Introduction to Leadership Training Workshop	Students self-assess coping/stress, communication, and leadership styles. Next, they engage in a 12-hour workshop led by external consultants with expertise in teamwork, leadership, conflict management and communication.
1 Iterative Contracting	Each team provides written iterative contracts during Weeks 2, 3, 5 and 7. Contract instructions are non-prescriptive, but general guidelines require that each team member have a defined role with tasks to complete and a deadline. In each iterative document, the students were to assess whether the task was completed, or what problems were encountered that prevented completion, and how uncompleted tasks were revised/reprioritized.
1 Grant Writing Tasks	Over the seven weeks, students complete a NIH grant document including: topic selection, specific aims, experimental plans with expected outcomes and alternative approaches, and explaining their ethical approach to their human subjects or animal subjects. (Authentic learning)
1 Oral Presentation Tasks	Students present the proposal three times: topic selection with gap in knowledge, specific aims with brief experimental plans, and the entire proposal at the end of the course. These presentations are in front of their peers and faculty, where they receive formative feedback.
1 Consultation with Biostatisticians	Students meet with biostatisticians to gain input on their statistical plan for their specific experimental designs (Authentic learning).
1 Expert Seminars/Workshops	Students receive seminar-based teaching on aspects of the research endeavor and grant writing including topics around experimental design, intellectual property, ethics and commercialization, for example.
1 Leadership Self-Efficacy Testing (Assessment)	Students completed the Kane-Baltes Leadership self-efficacy test[15] prior to leadership training (pre) and after the course is completed (post and in 2018 post-then).
1 Reflective Writing (Assessment)	At the end of the course, students are given a comprehensive prompt to undertake a long form reflection on their experience in the course, what they have learned, what they found beneficial/challenging, and what they will take with them moving forward.

Table 2

Course Elements mapped to Competencies.

Course Element	Gradudate Program CoreCompetencies	Team ScienceCompetencies
1 Introduction to Leadership Training Workshop	Personal and professional characteristics; Communication	Perspective seeking; Reflecting/ Analyzing
1 Iterative Contracting	Management; Communication; Conflict Management; Collaboration	Monitoring/Debriefing; Reflecting/Analyzing Creating change/ Development plans
1 Grant Writing Tasks	Research Skills; Management; Communication; Knowledge Content	Throughout all these tasks students are encouraged and supported by faculty and task design to achieve competencies in: Sharing unique information/ Promotive voice; Inquiring/probing; Reframing/Integrating; Perspective seeking; Acknowledging and including; Addressing issues and resolving conflict; Monitoring/ debriefing; Reflecting/analyzing
1 Oral Presentation Tasks	Communication	
1 Consultation with Biostatisticians	Management; Communication	
1 Expert Seminars/Workshops	Knowledge Content	Inquiring/probing; Reframing/integrating; Acknowledging and including
1 Leadership Self-Efficacy Testing (Assessment)	Personal and professional characteristics	Reflecting/Analyzing
1 Reflective Writing (Assessment)	Personal and professional characteristics; Communication	Reflecting/Analyzing

Table 2a

Pre-Post and Post-Then Kane-Baltes Self-Efficacy Self-Efficacy Testing Results: 2018 Cohort.

Statements	1-way RMANOVAp-value	Benjamini-Hochberg p-value(Pre-Post)	Benjamini-Hochberg p-value (Post-Then)
1. I have the necessary skills to perform well as a leader across different group settings.	0.025	0.304	0.006*
2. I can motivate group members to accomplish a biomedical research project.	0.005	0.402	0.0012*
3. I have the skills to build group members' confidence	0.004	*0.014**	0.0029*
4. I have the skills to develop teamwork toward accomplishing a group biomedical research project.	0.010	0.115	0.0072*
5. I can "take charge" when necessary in steering a team project.	0.008	0.016*	0.016*
6. I can communicate effectively with team members.	0.008	0.023*	0.023*
7. I can develop effective task strategies to help accomplish goals.	0.019	0.028*	0.041*
8. I have the skills to assess the strengths and weaknesses of the group.	0.001	0.004*	0.0015*
9. All 8 questions (over time and question)[a]	0.03#	5.1e-07*	<2e-16*§

#Greenhouse-Geisser epsilon correction to adjust for non-sphericity,

[a]2-way RM ANOVA was used for this analysis,

*indicates significantly different at the 0.05 level.

Table 3

Positive Themes. Example quotes and evidence of Team Science competencies.

	Theme	Quotes	Team Science Competencies
Positive	Empathizing with Group Members	*"It also requires me to be more cognizant of the backgrounds of my teammates and be able to anticipate when clarification will be needed due to lack of experience 1n this field."* (18–4-B)	*Monitoring and debriefing*
	Communication	*"We took preemptive measures to make communication as effective as possible starting from our first meeting."* (17–1-A) *"We were very intentional with our actions regarding the brainstorming process and got our entire team involved in filling the gaps"* (17–5-A) *"… we were all very open to constructive criticism and I don't feel anyone was offended by any comments or suggestions made throughout the course." (17–2-A)* *"But the supportive nature of the group helped me get out of my shell and be an assertive, confident contributing member." (17–2-D)*	*Creating change/development plans competency Inquiring/ Probing Reframing/ Integrating; Addressing Issues and resolving conflict Perspective seeking; Acknowledging and Including*
	Collaborative Work	*"We wrote in an online Google document so that everyone could see in real time what was being completed. (…). If two people were working at the same time we would instant message if we had questions or concerns so that we could work through a problem. (…) This method not only increased efficiency, but allowed our document to read as if it was written by one person rather than four" (17–1-B)* *"No one took lead and bossed everyone around, it was an atmosphere of people finding ways to work together." (18–3-C)*	*Perspective seeking; Acknowledging and including; Addressing issues and resolving conflict Reframing & Integrating; Monitoring/ debriefing*

Table 4

Negative Themes. Example quotes and evidence of Team Science competencies.

	Theme	Quotes	Team Science Competencies
Negative	Basic Communication	*"… on some level, we realized how different we were from each other early on, and this caused some issues with communication. Especially in the case of the relationship between B and I, I think none of us really knew how to handle each other, so we shut down and stopped talking to each other as much as we probably needed to. "* (17–3-A) *"Whenever working on team with varying levels of expertise, this may become muddied by a lack of communication and true understanding" (18–2-B)*	This showed a **lack** of competency in: *Sharing unique information/promotive voice; Inquiring/probing;* *Reframing and integrating*
	Poor Integration	*"This was reflected in our Initial presentation unfortunately—it was clear that we assembled our slides individually and never rehearsed our monologues as a group."* (18–2-D) *"The complete lack of honest communication really fractioned the group Into B and me and then A in another part."* (17–3-C)	This showed a **lack** of competency in: *Perspective seeking; Acknowledging and including a*ddressing issues and resolving conflict
	Theory-Practice Gap	*"Instead of me bringing further constructive knowledge on how to incorporate ideas, I was getting too technical and lost my empathy to acknowledge the utility of other ideas, even though we originally fostered an atmosphere of education " (Participant 17–4-B)* *"Again, I was just in avoidance mode (…)"* (17–3-C)	This theme included many different examples showing a **lack** of competency across all Team Science competencies but especially: *Addressing issues and resolving conflict; Monitoring/debriefing; Reflecting/Analyzing*