Revisiting Tuckman's Team Development Model in First-year Engineering Multicultural Teams

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Introduction

Engineering classrooms have adopted team-based learning as a popular and effective pedagogy for a long time [1-3]. Given the booming of computer-assisted learning technologies, instructors could easily observe the different ways of interaction and collaboration across teams and among team members within the same team. Perhaps most of the time, the student teams function just fine. Yet instructors might actively or passively notice the existence of dysfunctional teams, where team dynamics were impaired, and team members developed negative attitudes towards one another [4-5]. Furthermore, in other situations, social loafing might exist within student teams but sometimes hardly get instructors' attention [6]. When such situations happen, the benefits of cooperative learning are compromised and at risk [7].

Scholars and practitioners have proposed ways of trainings to support student team success. Using Goal-Role-Process-Interpersonal-Relationship models, students wrote memos to reflect on their team dynamics and development [8]. Students can overcome potential tensions in teamwork through conflict resolution training [9]. The teamwork Failure Prevention Questionnaire, as the name suggests, is a instrument that can help teams potential weakness [10]. Instructors commonly use Tuckman's team developmental model [11-12] to help teams understand team processes—to preview what the team might experience next and to move as quickly as possible to a higher level of functioning [13-15]. Due to first-year students' lack of maturity and experiences working in multicultural teams, we wonder if the developmental models of such student teams could be categorized or essentialized as Tuckman's model. In addition, literature pointed out the influence of individual differences on team dynamics, we are motivated to study in the context of multicultural teams so as to provide the opportunity for researchers and instructors to reflect and be mindful of growth-oriented and equity-mindset team building and training. Therefore, we propose the research question of this study: **compared to Tuckman's team developmental model, how did the dynamics/stages of first-year engineering multicultural teams evolve**?

In the following sections, we first synthesize the literature related to Tuckman's Team developmental model to articulate the definitions and characteristics of the proposed stages. We will then summarize the relevant and pertinent critiques of the models. By situating this work in engineering education, we examine the research team's positionalities. Further, in the methodology section, we describe the participants and context of this study, data collection and analysis, and some limitations. Afterwards, we present the team developmental stages students perceived along with their narratives and discuss the unique patterns that emerged in the two studied cases. We further discuss the discrepancy of the team development stages in the studied cases with Tuckman's model with an emphasis on the impact of contextual factors associated with the learning envionments. Finally, we summarize our main critiques and arguments on the transferability of Tuckman's model in first-year engineering student multicultural teams and offer some practical teaching suggestions for instructors.

Literature Review

Tuckman's Team Developmental Model

This model proposes that a team typically experiences five teaming stages, namely, forming, storming, norming, performing, and adjourning [11-12]. In the **Forming** stage, team members are typically gathered together to work to complete task jointly. Although some dyads within the team might know each other, the whole team starts to establish team dynamics of interaction. Gradually, team members develop a better yet blurry understanding of the distributed expertise

and diverse personality and characteristics of each other. Before fully internalizing and synthesizing the most appropriate way to work with others, team members might accumulate team conflict and friction. When the team conflicts become salient, the team enters the **Storming** stage. At this point, team members collaborate with tension and discomfort and might emotionally react to the assigned task and other members. Among course-based students, team members usually experience conflict as a lack of consensus on how to split the tasks and who will do each, which might discourage some people from actively and meaningfully contributing [16]. If the team generally resolves those conflicts, then the team gradually establishes new team dynamics and norms in the stage of **Norming**. Team members now adapt to learn how to work with people different from themselves. Moreover, people tend to be open to new ideas, allow alternative interpretations and approaches to solve tasks, and start to focus on execution [17]. The main characteristic of this stage is that the team develops the working mechanism to effectively guide their collaborative work with strategies and plans. Continued collaboration then leads to the fourth stage, **Performing**. At this stage, all members understand the expertise, position, working style, and personality of everyone to a certain degree. In addition, the team could prevent or even harvest from potential conflicts with constructive conversations. **Adjourning** is the last stage and refers to the period of time when the team disbands or finishes the project [11-12]. After successful team experiences, teammates share feelings of sadness, express a willingness to work more in the future, recognize and appreciate the importance of each other, and reflect on their teaming experiences together.

Criticism of Tuckman's Model

Evidence suggested that the Tuckman model was not applicable to all teams because teams of students and of management in organizations were formed for different purposes and contexts, which shaped the team development stages [16]. Tuckman's team development model has been criticized for its overgeneralization for several two major issues: validity of linearity and inflexibility [17], and neglect of external factors [18-20]. Therefore, we concern whether Tuckman's model could well capture the team dynamics of engineering student learning teams.

Linearity and flexibility. The Tuckman model implied that all teams went through the stages in a neat and predictable sequence [11], which might violate the actual situation in working teams confounded by many contextual factors [21]. In Tuckman's model, the termination of a team was assumed, but it was not true in many cases. For example, researchers who have established a long-lasting team, might run multiple projects simultaneously when making different progress, similar to other working teams of an organization [22]. Scholars also indicated the possibility that a team could start directly from the norming stage and might end in any of the other stages except forming [23]. Similarly, doubts were raised about whether a group would necessarily follow a fixed sequence and about the potential effects of external and contextual factors [24]. Furthermore, the model also suggested that the stages of group development must be completed before moving on to the next. However, it was argued that the stages could overlap and occur in a non-linear or cyclical fashion, and some stages might be skipped entirely or revisited multiple times [23].

External factors. One explanation for the previous two areas of criticism falls on the neglect of external factors that influence the team dynamics. Kozlowski and Ilgen [19] proposed the following elements to understand a team's developmental stages and dynamics: the environment that a team operates in, social and cultural norms that co-develop within a team, time limitation, and demographics of the team.

Studies showed how team interactions were shaped by individual differences of team members, particularly in multicultural teams, such as age, cultural backgrounds and other factors [19, 21]. In addition, people's perceptions of their team and teammates also influenced team development. For example, the storming stage expected the team experienced conflict, which contained three types: task conflict (what task to deal with), process conflict (how to deal with the task), and relationship conflict [25]. Yet, people might not realize the existence of all types of conflict and only emphasize one certain type of conflict while ignoring other types of conflict. If the team members were good friends, or if there was a high attractiveness bias, they might refuse to claim their team would go through the storming stages. In response to this limitation, researchers have proposed incorporating individual differences into the model [26], where an individual's developmental process can be examined and integrated into the group's developmental process [19].

McGrath [20] suggested several external factors that could influence the team development stages, such as environmental stability, team size, resource availability, team goals, leadership style, and communication patterns. Environmental stability referred the degree to which the team's environment was predictable and consistent – the development of a team might followed the patterns described in Tuckman's model only when the teaming environment was relatively stable. Increased team size might result in more team management issues and conflicts, which was salient in the stroming stage. Tuckman's model was developed for small groups and criticized for being not applicable to larger groups [19]. In this study, the student team size was four – matching Tuckman's small group context – so any lack of fit of the Tuckman model was not due to team size. The resources available to the team, e.g. time, equipment, and information, would also influence the team dynamics. Depending on the team goals, leadership style, and communication patterns, the team might either get stuck in a messy situation and create conflicts, or develop team cohesion to work together to overcome issues caused by the limited resources.

Research positionalities

As a research team, we are motivated to conduct this study because we all observe and participate in multicultural teams and recognize the different genres of team dynamics and developmental patterns. Three members of our research team are originally from different regions of Asia, and one member is domestic but with extensive experiences teaching and working with international students, scholars, and staff. Three out of the four authors are not native English speakers. As a team, we take on different educational roles that provide perspectives from the student, the teaching assistant, the instructor, and the administrator. Although every member of our team identifies as male, some are active members or allies of the LGBTQIA+ community, and we have experienced or observed particular team dynamics related to marginalization of members of that community. Our identities and experiences provide the lenses by which we interpret the social interactions among student teams under investigation. While we recognize and try to bracket the extent to which the intersection of our privileged and minoritized identities shapes our cognition and interpretation of student team phenomenon, we cannot be fully aware of how our implicit biases and beliefs project on this study. Nonetheless, the research team aims to analyze, interpret, summarize, and present the stories of our participants transparently and undistorted in a narrative form.

Methodology

Participants and Context

With the approval of our institutional review board (IRB), this study was conducted at a large land-grant, research-intensive PWI university in the Midwest. First-year engineering students enrolled in an engineering foundation course in the summer of 2022 were recruited. A majority of students in this course got ahead with their college study and a very small portion of students in this course was between their first- and second-year due to transferring into engineering majors. Specifically, we targeted to recruit participants who worked in multicultural teams, which included at least one international student. Althrough we acknowledge that all-domestic teams could also experience great cultural shocks and differences, we assume that the effect of cultural differences in teams having international students might be relatively easy to centralize in team dynamics. The motivation for this effort was to investigate if the classical model of team developmental sequence was appropriate for the contemporary context, where engineers are expected to work with different others and in multicultural teams [27]. As Tuckman's model was proposed and generalized based on work in or before 1970s [11-12], and the work made no explicit mention of the demographics of the study participants, we assume the study's teams were composed from a culturally homogeneous population.

The recruitment email in our study was sent out by the course instructor in the proceeding Fall semester of 2023, outside our research team. Although we had hoped to have more participants so that we could balance the sampling representation in terms of gender, race/ethnicity, international status, and native language, we were only able to recruit two participants successfully. After the interviews with the two participants, we also asked for referral to their classmates to join in this study, but this attempt at snowball sampling yielded no additional participants. The basic information of the participants and their teammates is presented in Table 1 with self-identified pseudonyms. We want to declare that all the information in Table 1 was provided by the interviewee (Eric and Maxwell) with their best knowledge so that there exists a risk of inaccuracy. Note that the only two interviewees were male students, who might have different interpretions and perceptions of team dynamics different from female and non-binary students with less power, especially team conflict. By providing this information, we hope that readers could be informed of the unrepresented samples in this. study and use their own judgement to consider the transferability into other contexts.

Students in the summer class were randomly assigned into ad-hoc teams at the beginning of the class for one week and completed one team assignment. Subsequently, students were reassigned into teams that remained together until the end of the term for another three weeks. Teams were formed using the Team-Maker tool [28] with the primary criteria being schedule compatibility and avoiding isolating women and students who are minoritized on the basis of race/ethnicity. The latter criterion was not met in the case of Team 1 in the table above. In this research, we only focused on the team development and dynamics of the permanent teams. The summer course was accelerated and intensive, condensing a 16-week course into a 4-week course, so teams needed to finish the term design project in the last two weeks working in an intensively active and collaborative learning environment. Besides drafting the team chart as the "Code of Cooperation", student teams in this course were required to complete three team assignments and then collaborate on a term final project on the second half of this course.

Table 1. Participant and associated team member summary

Team	Pseudonym	Pronouns	Race/ethnicity	International student?	Origin
1	Eric	He/him	Hispanic	No	West-USA

	T1A	She/her	White	No	Midwest-USA
	T1B	He/him	White	No	Midwest-USA
	T1C	She/her	White	Yes	Europe
2	Maxwell	He/him	White	No	Midwest-USA
	T2A	He/him	Native	No	Unclear-USA
	T2B	He/him	White	No	Midwest-USA
	T2C	He/him	Asian	Yes	South Asia

Data Collection

Data was collected via semi-structured, one-to-one interviews in the middle of October 2022. The interview protocol was developed to guide participant to reflect on their team experiences chronologically and capture their reactions to the team interaction and dynamics. We focused on soliciting significant milestones and key events from the participants and attempting to understand the roles of everyone in the team and how the person(s) influenced the dynamics. Therefore, we drafted the protocol based on the framework of Tuckman's team developmental sequence model [11-12] discussed in the literature review section above. Our research team carefully examined and revised the interview protocol to ensure the quality, relevance, and accessibility of the questions [29]. We acknowledge the research design of this study might influence of participants' retrospective memory, which may have led to a biased recall of positive experiences and a downplaying of negative experiences, we attempted to mitigate this limitation by utilizing a semi-structured interview format that guided participants through Tuckman's team development stages. The first author conducted the interviews with the following guiding questions:

- Could you please introduce yourself and your teammates regarding demographics?
- Could you please discuss your first impression when interacting with your teammates?
- Could you talk about how your team developed the team "Code of Cooperation"?
- How did your team perform at the beginning?
- Did your team encounter a moment of conflict or disagreement? What happened?
- How did you resolve the conflict issues?
- How were the team dynamics different from the middle to the beginning of the stage?
- How did your team perform in the later stage?
- Could you please discuss how did your team complete the final term project?
- How did you feel in the end? Why?

We also asked follow-up questions for clarification or more details, especially inquiring for specific examples to support participant's claims. All interviews were recorded via Zoom.

Data Analysis

Data analysis started by transcribing each interview audio file into verbatim, using Zoom's live transcription option. Two authors manually examined and revised the transcription documents by listening to the recorded audio. After obtaining the clean interview data documents, we first noted our first impressions in memos and annotations, and then integrated them for further interpretations, using an interpretive data analysis model [30-31]. We then collaboratively and deductively coded the data [32, p.81] based on the definitions/descriptions of team development stages discussed above, namely, forming, storming, norming, performing, and adjourning [11-12]. Due to the small number of data we had, we chose not to inductively seek the commonalities, but interpreted the results within the context of each team so as to allow a more

profound understanding of the team dynamics, which might not be necessarily coherent or internally consistent [33-34]. Finally, participant quotes have been edited for clarity and readability in this article (e.g., grammar errors were corrected).

Results

Forming

Once the student teams were formed, they were assigned to an ice-breaking activity, where students introduced themselves to other teammates with instructor-provided questions to understand each other better. This activity provided an opportunity to make a first impression on other team members, which was important for the team to get started [35].

When asking about participants' first impression of other teammates, Eric (Team 1) felt uncomfortable in the new team and indicated that: *"First, the impression was awkward and team members were not very outgoing… It was just going to be socially awkward… I did not feel comfortable… After the ice-breaking, it just kind of got quiet."* On the contrary, Maxwell (Team 2) got to know about his teammates beyond the first impression of their personalities. He explicated that: *"They were probably not funny people, you know. They were sharp. Their math and science are well-established… T2A kept more to himself at first, so he was slower to open."*

In forming stage, team members have relatively little knowledge about each others' working styles and preferences, which might lead to inefficient planning towards finishing the project [16]. We further asked the participants about their initial strategy for the team assignments. Eric shared his experience of starting from scratch:

> *"We didn't really have a plan and the most issue was who was going to do what…we didn't know the strengths of each other... The first thing we did was the map, but we never really had a full plan... I had no idea what T1C was doing for the project, and I said that in my [peer evaluation] review that I was unaware of what she was doing."*

Although they did not know each other very well, Maxwell was still able to lead the team to initiate the strategy to distribute and execute the work with a plan. He stated:

> *"They were good at problem-solving, and we could delegate tasks very quickly. We all knew we had different backgrounds, but we matched well… [we] read it (idea) aloud, spouting off ideas and like, 'keep that one', 'don't keep that one... I was the one who was organizing, So I was pointing out to look at those spots in the rubric. I was telling team number one to draw the diagram and telling T2B to dig into that section."*

Storming

We tried to examine the participants' experiences of the storming stage featuring tensions and team conflicts. Although we used different phrases and even introduced the connotation of the three types of team conflicts to our interviewees from different angles, they reported minimal to no conflicts existed in their teams.

Eric acknowledged the outcome of the project was good, and declared no team conflict: *"I think because we know such short-handed on time. We just had to get along. But there were no conflicts or anything."* After we invited Eric to discuss more about the most pressing issue happened in the team, Eric asserted that poor communication could cause conflict: *"I think the biggest conflict maybe could have been communication… Otherwise, it wasn't an issue at all."*

Maxwell, on the other hand, insisted no conflict existed in his team and everything went well as they planned their work on practical actionable items:

"[We had] very little, but none [conflict] in most sections. Very little to no disagreement in how we're going to lay it out because we only put things (action items) on paper. That was actionable… So there's no reason to disagree with something practical and actionable… I deal with it on a regular basis."

Norming

At the norming stage, the team should be cohesive and works effectively together towards a common goal [11-12]. The team has developed a reasonable strategy to tackle their tasks [35]. Team members also know each other's abilities and try to help each other with tasks [36].

After the first project, Eric's team started with planning and became more interactive, which led to effective collaborative learning. He claimed:

"We did not have any plans at the beginning. But then in the second project, after we had got an idea of what we were doing, we started planning out at the beginning. It helped us to become a lot more interactive when it came to plan for a group… We asked each other constantly."

Maxwell mentioned five times that all team members had to be on time, and they were clear about their roles and worked together to achieve the same goal of finishing the assigned tasks based on the agreed plan.*"According to the time and out goal, we had to work together, and each person knows [their] roles."* In Maxwell's team, although they tried to rotate the roles of everyone at the beginning, team members' roles were eventually switched into a more stable mode. He explained:

"One of the things we changed from the first draft to the second draft of team code of cooperation was rotating roles every week. When we revised that we said delegating tasks [to each person] had a number of strengths. It's not necessary to rotate roles. If you have strengths you could play into, lean into that and do better work with that than being assigned to new one every time."

Clearly, both teams later developed their own strategies to cope with team projects for creating a working plan and assigning members with fixed roles.

Performing

Team members in this stage have adapted to and become comfortable working together. They have established clear confidence lines of communication and tried to help each other with different tasks as they could now estimate the load and difficult levels of tasks [11-12].

Eric expressed his attachment to the team and indicated that the team worked well later on.

"[We were] kind of lucky getting closer...It (relationships) was more realistic... After we had that first project, we kind of got to know each other a lot more because we were meeting up for the projects… The later project was lot easier; I think. By the time we got to know exactly what you're doing. The workload was lower except for the last part. But as a team, [we] did that together. That was the difference."

For Maxwell's team, trust and cohesion grew as the team identity. He enjoyed the time with his team and reported:

"We were so such good buddies! By the end of it that we just enjoyed the time together, and we forgot about the time we set. Like if we said we were going to be out of there by 11, we might have been walking out there at 2 AM with big smiles on our faces and all the work done."

In this stage, team members reach a strong sense of cohesion, and members can better support each other and collaborate effectively compared to the norming stage [11-12]. Members also have a clear understanding of their roles and responsibilities and can work interdependently to achieve their goals [23]. Both Eric and Maxwell described an example of how they collaborated with their teammates.

> *"When it came to [choose the design of] slides we agreed on letting somebody design and pick the theme, I remember T1A took over the kind of designing the slides. She also helped us with a lot of the idea proposals… the result of our team was very satisfying…"* - Eric
>
> *"[T2A has] kind of different backgrounds [as homeschooling]… [T2A] kept more to himself at first, so he was slower to open but once he opened up to our group, he was, he felt like that was his place. Then he was just on top of it. It took a little bit longer [for him] to become integrated into the team."* - Maxwell

Adjourning

At the end of the semester, the project was completed, and the team was dismissed. Both Eric and Maxwell were positive about their teammates. Eric reflected: *"I think we got along… we would make good teammates… I think we're on the same page, so I think we have just that common ground of (dealing with)struggling that way."* And Maxwell complimented: *"It was fun to work with friends."*

Discussions

Based on the results, we visualize the team development patterns of Eric's (Team 1) and Maxwell's team (Team 2), as shown in Figure 1. We could like to centralize our discussion on three aspects to criticize Tuckman's model, which are the "missing" storming stage, nonlinearity of the development stages, and effects of contextual factors.

The "Missing" storming stage

The storming stage was theorized to occur after the forming stage, when team members have become comfortable with each other and are starting to interact more openly [18]. Despite the increased interaction, the team could experience conflicts and tensions when members assert their opinions, ideas, and needs. There may be disagreements about the team's goals, priorities, and the roles and responsibilities of each team member [35]. Despite that the disagreement and accomendation may occur in forming stage, the conflict charactertized in the forming stage is theorized to be more severe and negative. Therefore, we choose not to overlap forming stage and storming stages completely in Figure 1. Similarly, we also don't consider the trivial or minor disagreement as conflict. In both cases, participants did not recognize team conflicts or tension, which matched the research finding that the majority of students (74%) did not notify their instructors of team conflicts [37]. Further, students reported incidents of experiencing process conflict, where Eric mentioned that "*the volume of work and tasks was huge when considered the [give] time [to complete]*." Having no or little clues on how to tackle the team assignments, Members of Eric's team might have different ideas and approaches to address this issue. Yet, Maxwell's team focused on applying the strategy to develop practical action items to deal with the issue, which dodged this problem. In addition, a blurry understanding of each member's expertise and strengths might also contribute to a team's process conflict. As presented in the results, Eric was unaware of T1C's contribution and Maxwell mentioned the late integration of T2A. The accelerated course put a particular constraint on time, which the participants felt

inhibited the opportunity for – or at least the perception of – minor teaming issues. More will be discussed in the external factors section.

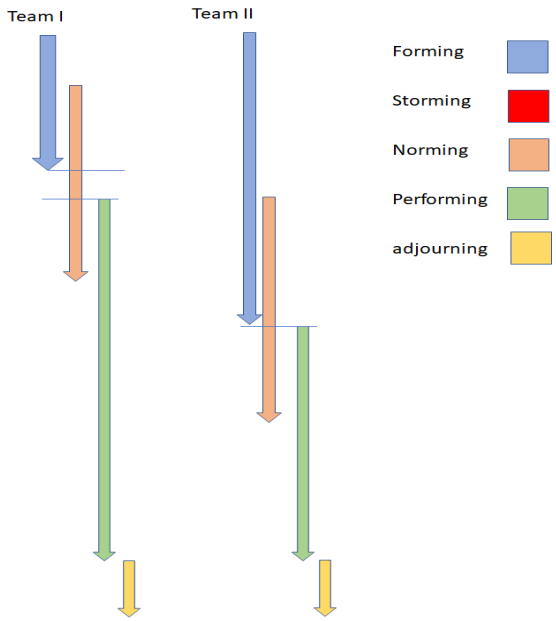

Figure 1: Perceived Developmental Stages of Interviewees' Engineering Student Teams

Non-linearity of Tuckman's model

As shown in Figure 1, the "missing" storming stage observed in this study's cases departed from the linearity assumption of the Tuckman's model. We also noted that the boundary of each team's developmental stages was not clear and even overlapped. In both cases, teams started to develop norms and working strategies from the beginning, which caused forming and norming operations to be convoluted. Furthermore, although the teams achieved reasonable outcomes and were satisfied with them in the middle of the semester, they still sought opportunities to improve their team functioning. This phenomenon demonstrated that the norming and performing stages got mixed, which corresponded to other literature claiming the stages of team development may overlap and occur simultaneously [26]. In addition, our cases also provided additional evidence to support the claims that (1) Tuckman's model might not be applicable to all groups; and (2) the stages might not be completed in the same sequence for all teams [19].

Effect of Contextual factors

we further acknowledged that several factors influenced the team development patterns, including the support and feedback of instructors and teaching assistants, the fast-paced course schedule and time constraints, the preconceived assumptions of teammates, and the experiences of working with a random-assigned ad-hoc team at the beginning of the course. Those factors matched with several external factors introduced in the literature review section [18-20].

In learning teams, instructors and TAs provided guidance, support, and feedback to help teams avoid certain hurdles. Group members often relied on guidance, as they looked to establish clear roles and responsibilities and set goals for the group [21]. We know that team members received a description each assignment and project, and had good access to the teacher's assistance which allowed them to clarify the purpose and steps of tasks. Besides, teams got to better know each

other and somewhat understood what they should do. So they could integrate all information and expected support to plan and divide their work.

Participants took a summer course that condensed a 16-week content into four weeks so that the spacing of assignments created psychological burden to make students feel tired and overwhelmed. Eric claimed that *"we had class every day from 8:30 to 10:30, which is very exhausting after a while. At that point it became very repetitive, and it both just like he didn't want to work on that project every day*." If a student fell behind, they might need to make extra effort to catch up, which could be stressfull. However, this setting also forced students to collaborate more closely and frequently.

On a related note, Maxwell indicated his preconceived assumptions about teammates that "*one of the things that makes summer start an early start different than the regular semester is because everyone's already committed, and they want to get ahead… They are high achieving and they will work harder than the others in the class.*" His positive attitude towards teammates was likely to translate into his friendly reactions and behaviors to them.

Lastly, this study focused on the "permanent team" experiences of participants where the teams spent majority of time working together towards the completion of the final term project. Yet, they repeatedly mentioned the lessons they learned from the "temporary" and randomly-assigned team. For example, they inherited the collaboration strategy used in the temporary team into their permanent team at the beginning, such as how to make a work plan, how to distribute tasks, and how to communicate more effectively.

Conclusions

From the two cases of multicultural engineering student teams, we reveal the students' perceptions of their team development stages and identify three aspects that misalign with Tuckman's model. In our cases, students reported no observed storming stage, overlapped forming and norming stages and norming and performing stages, and several contextual factors that shaped their team experiences and team development stages. Students teams were formed to learn and support each other and, in this particular context, student teamwork experiences cannot be aligned well with the linearly prescribed stages. Team development is a complex process confounded by a variety of factors, which makes the sequence less predictable. While we criticize the validity and applicability of Tuckman's model in student engineering multicultural teams, several lessons are valuable for instructors to consider. Firstly, it is significant to provide a welcoming and supportive learning space to allow student to learn in and with teams. Secondly, instructors could cultivate a positive environment, and growth-oriented and equity-minded protocols to acknowledge the possibility of team conflicts and prepare to suggest conflict resolution strategies. Similarly, instructors also want to encourage students to trust their teammates and allow them to improve. Lastly, instructors could guide students to reflect on their teamwork experiences to identify the areas to enhance and work on them.

References

[1] Johnson, D. W., Johnson, R. T., & Smith, K. A. (1998). *Active learning: Cooperation in the college classroom*. Interaction Book Co.

[2] Murzi, H. G. (2014). Team-based learning theory applied to engineering education: A systematic review of literature. *ASEE Annual Conference & Exposition*.

[3] Najdanovic-Visak, V. (2017). Team-based learning for first year engineering students. *Education for Chemical Engineers*, *18*, 26–34. https://doi.org/10.1016/j.ece.2016.09.001

[4] Hwong, N. C., Caswell, A., Johnson, D. W., & Johnson, R. T. (1993). Effects of cooperative and individualistic learning on prospective elementary teachers' music achievement and attitudes. *The Journal of Social Psychology*, *133*(1), 53–64.

[5] Johnson, D. W., Johnson, R. T., Roy, P., & Zaidman, B. (1986). Oral interaction in cooperative learning groups: speaking, listening, and the nature of statements made by high-, medium-, and low-achieving students. *The Journal of Psychology*, *119*(4), 303–321.

[6] Jassawalla, A., Sashittal, H., & Malshe, A. (2009). Students' perceptions of social loafing: It's antecedents and consequences in undergraduate business classroom teams. *Academy of Management Learning and Education*, *8*, 42–54.

[7] Felder, R. M., & Brent, R. (2016). Teamwork skills. In *Teaching and Learning STEM: A Practical Guide* (pp. 245–269). John Wiley & Son.

[8] Jaiswal, A., Karabiyik, T., Thomas, P., & Magana, A. J. (2021). Characterizing team orientations and academic performance in cooperative project-based learning environments. *Education Sciences*, *11*(9). https://doi.org/10.3390/educsci11090520

[9] Magana, A. J., Karabiyik, T., Thomas, P., Jaiswal, A., Perera, V., & Dworkin, J. (2022). Teamwork facilitation and conflict resolution training in a HyFlex course during the COVID-19 pandemic. *Journal of Engineering Education*, *111*(2), 446–473. https://doi.org/10.1002/jee.20450

[11] Tuckman, B. W. (1965). Developmental sequence in small groups. *Psychological Bulletin*, *63*(6), 384–399. https://psycnet.apa.org/journals/bul/63/6/384/

[12] Tuckman, B. W., & Jensen, M. A. (1977). Stages of small-group development revisited. *Group and Organization Studies*, *2*(4), 419–427.

[13] Godwin, A., Kirn, A., Langus, T. C., Pearson, N. S., Major, J. C., & Rodríguez-Simmonds, H. E. (2020). Interpersonal interactions in engineering teams: Findings from a multi-year mixed methods study at three institutions. *2020 ASEE Virtual Annual Conference*.

[14] Jaiswal, A., Thomas, P. J., Karabiyik, T., Perera, V., & Magana, A. J. (2021). Assessing the impact of transition from face-to-face to online instruction on team cooperation. *2021 ASEE Virtual Annual Conference*.

[15] Van Tyne, N. (2022). Before and after: Team development in virtual and in-person transfer student engineering design teams. 2022 ASEE Annual Conference & Exposition. Minneapolis, MN.

[16] Johnson, S. D., Suriya, C., Yoon, S. W., Berrett, J. V, & Fleur, J. La. (2002). Team development and group processes of virtual learning teams. *Computers & Education*, *39*(4), 379–393. https://doi.org/10.1016/S0360-1315(02)00074-X

[17] Hal, T. (2015). Does cohesion positively correlate to performance in all stages of the group's life cycle? *Search.Proquest.Com.* https://search.proquest.com/openview/a1535815858bbebd78fe6658dedd04dc/1?pq-origsite=gscholar&cbl=38870

[18] Bonebright, D. A. (2010). 40 years of storming: A historical review of tuckman's model of small group development. *Human Resource Development International, 13*(1), 111–120. https://doi.org/10.1080/13678861003589099
[19] Kozlowski, S. W. J., & Ilgen, D. R. (2006). Enhancing the effectiveness of work groups and teams. *Psychological Science in the Public Interest, 7*(3), 77–124. https://doi.org/10.1111/j.1529-1006.2006.00024.x
[20] McGrath, J. E. (1984). Groups: Interaction and Performance. Englewood Cliffs, NJ: Prentice-Hall.
[21] Egolf, R. S. (2022). *Exploration of Tuckman's Model of Group Development: Perceived Applications and Prevalence among Adventure Education Practitioners* (Master's thesis). ProQuest Dissertation & Thesis Global database. (UMI No. 29212277). https://www.proquest.com/dissertations-theses/exploration-tuckman-s-model-group-development/docview/2674282718/se-2
[22] Chidambaram, L., & Bostrom, R. P. (1997a). Group Development (I): A Review and Synthesis of Development Models. *Group Decision and Negotiation, 6*(2), 159–187. https://doi.org/10.1023/A:1008603328241
[23] Dexel, L., Martin, B., Black, L., & Yoshino, A. (2010). Re-Thinking Group Development in Adventure Programming: A Qualitative Examination. *Research in Outdoor Education, 10*(1), 74–86. https://doi.org/10.1353/ROE.2010.0008
[24] Arrow, H. (1997). Stability, Bistability, and Instability in Small Group Influence Patterns. *Journal of Personality and Social Psychology, 72*(1), 75–85. https://doi.org/10.1037/0022-3514.72.1.75
[25] Jehn, K. A., & Mannix, E. A. (2001). The dynamic nature of conflict: A longitudinal study of intragroup conflict and group performance. *Academy of management journal, 44(2), 238-251.* https://doi.org/10.5465/3069453
[26] Gersick, C. J. G. (1991). Revolutionary change theories: A multilevel exploration of the punctuated equilibrium paradigm. *Academy of Management Review, 16*(1), 10–36. https://doi.org/10.5465/amr.1991.4277907
[27] ABET. (2019). *Criteria for accrediting engineering programs (2019-2020)*. ABET. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2019-2020/
[28] Layton, R. A., Loughry, M. L., Ohland, M. W., & Ricco, G. D. (2010). Design and validation of a web-based system for assigning members to teams using instructor-specified criteria. *Advances in Engineering Education*, *2*(1), 28.
[29] Merriam, S. B., & Tisdell, E. J. (2014). *Qualitative research: A guide to design and implementation.* (4th ed.). San Francisco, CA: Jossey Bass.
[30] Rodriguez, G. M. (2013). Power and agency in education: Exploring the pedagogical dimensions of funds of knowledge. *Review of Research in Education, 37*, 87–120. https://doi.org/10.3102/0091732x12462686
[31] Willis, P. (2001). The "things themselves" in phenomenology. *Indo-Pacific Journal of Phenomenology*, *1*(1), 1–12. https://doi.org/10.1080/20797222.2001.11433860
[32] Miles, M. B., Huberman, M. A., & Saldana, J. (2014). *Qualitative Data Analysis: A Methods Sourcebook*. SAGE Publications.
[33] Dringenberg, E., Kramer, A., & Betz, A. R. (2022). Smartness in engineering: Beliefs of undergraduate engineering students. *Journal of Engineering Education*, *111*(3), 575–594. https://doi.org/10.1002/jee.20463

[34] Pawley, A. L. (2019). Learning from small numbers: Studying ruling relations that gender and race the structure of U.S. engineering education. *Journal of Engineering Education*, *108*(1), 13–31. https://doi.org/10.1002/jee.20247
[35] Hurt, A. C., & Trombley, S. M. (2007). The punctuated-Tuckman: Towards a new group development model. Paper presented at the International Research Conference in The Americas of the Academy of Human Resource Development. Indianapolis, IN.
[36] Lawrence, M., Oldfield, S., Rider, M., & Clark, C. (2016). Stages of group development: An empirical test of Tuckman's hypothesis. *Group & Organization Management, 7*(2), 180–193. https://doi.org/10.1177/002188637100700204
[37] Mostafapour, M., & Hurst, A. (2020). An exploratory study of teamwork processes and perceived team effectiveness in engineering capstone design teams. *International Journal of Engineering Education*, *36*(1B), 436–449.