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COMMENTARY

Fostering TBL Success at Alfaisal University: A Complex Adaptive Systems Approach

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Abstract: This study explores the implementation of Team-Based Learning (TBL) at Alfaisal University's College of Medicine through the lens of Complex Adaptive Systems (CAS) theory. The research question investigates how the application of CAS principles can enhance the implementation and effectiveness of TBL in medical education. The study employed a convergent parallel mixed methods longitudinal design, integrating quantitative performance metrics and qualitative themes. Quantitative analysis revealed modest improvements in individual and team-based learning scores, with a promising trend of students moving from the lower to the higher quartiles over time. Qualitative insights aligned with CAS principles, highlighting the adaptive implementation, emergent outcomes, self-organization, positive feedback loops, and depth of learning facilitated by TBL. The findings demonstrate the value of a CAS-informed approach in navigating the complexities of educational change and fostering a more resilient and adaptive educational model. The study contributes to the understanding of how CAS theory can guide the successful implementation of innovative pedagogies like TBL in medical education.

Keywords: educational change, adaptive implementation, emergent behaviors, feedback loops, self-organization

Introduction

Medical education is undergoing a significant transformation, shifting from the conventional lecture style teaching to more interactive and engaging methods. Team Based Learning (TBL) has emerged as a promising pedagogy in this changing landscape.[1–3] However, introducing these approaches in established educational institutions comes with various obstacles often needing adaptations, across various levels of the system.[2,4] The shift to TBL at Alfaisal University's College of Medicine in 2013 aimed to accommodate growing student numbers but faced challenges with faculty resistance to new methods and students' unfamiliarity with active learning.[5]

This research delves into the implementation of TBL, at the College of Medicine, Alfaisal University, through the lens of Complex Adaptive Systems (CAS) theory.[6–8] By considering the institution as a CAS, our goal is to uncover dynamics of change and advancements in medical education. Our research question is: How can the application of CAS theory principles enhance the implementation and effectiveness of TBL in medical education?

Complex Adaptive Systems are capable of learning, adapting and evolving in response to changing conditions. Essential aspects of CAS includes non-linear interactions between system components, the emergence of new behaviors and patterns, self-organization and adaptation, and continuous learning through feedback loops.

By applying CAS principles to our TBL implementation, as seen in Figure 1, we aim to recognize the non-linear nature of change in educational systems, nurture emergent behaviors that contribute to effective learning, establish feedback loops for continuous improvement, empower various agents (students, faculty, administrators) within the system.

To facilitate successful implementation, a dedicated TBL team was formed, understanding the process as a complex adaptive system. This team played a pivotal role in changing the educational landscape, acting as a driving force for

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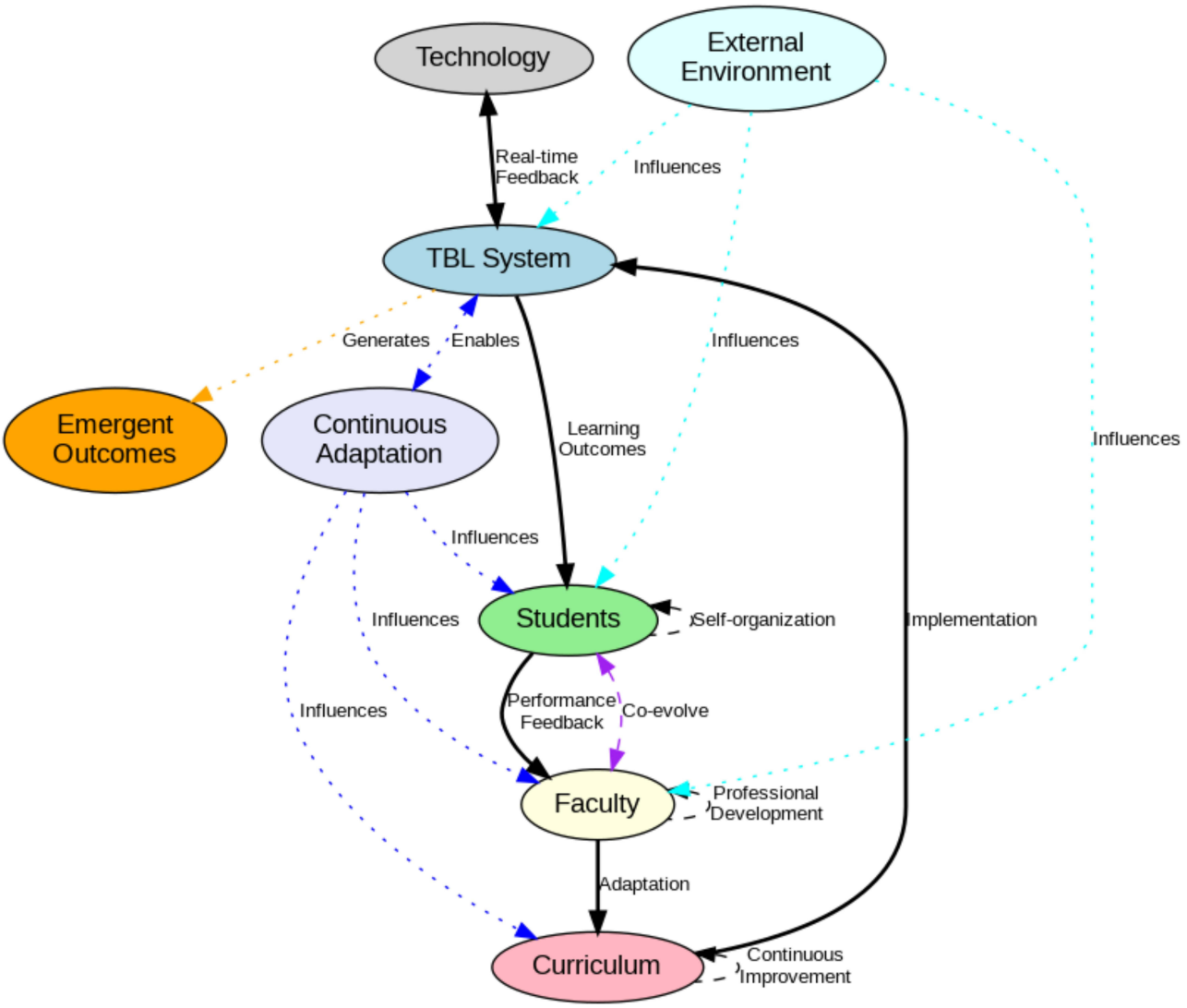

Figure 1 Illustrates the conceptual model of a TBL system viewed through the CAS lens, displaying the interconnections between various components such as students, faculty, curriculum, technology, and the external environment.

continuous improvement. They were proactive in adjusting the TBL model to meet the evolving needs of faculty and students, creating tailored resources and challenging assessments.

The strategic approach of the TBL team exemplified a key principle of CAS: the value of gradual adaptation that allows for ongoing adjustment and improvement.[7,9,10] Initially, we introduced a hybrid TBL model that combined traditional lectures with TBL sessions focused on specific weekly learning objectives.[5] This strategy aimed to secure initial support from faculty members while also addressing concerns regarding the shift.

This study describes our journey of implementing TBL at Alfaisal University's College of Medicine since 2013, guided by CAS theory. We explore how this approach has primed our strategies, helped overcome challenges, and contributed to the development of a more resilient and adaptive educational model. Despite lacking formal training in adaptive action cycles, the team employed informal and formative assessments to continuously enhance their approach, demonstrating the iterative, adaptive process within CAS, as stakeholders respond to feedback and adjust strategies for improvement.

Methodology

Research Design

This study employed a convergent parallel mixed methods longitudinal design, framed within the CAS theory.[11–15] This approach was chosen to capture the multifaceted nature of TBL implementation in medical education over an extended period. The mixed methods approach integrates quantitative performance metrics with qualitative themes, while the longitudinal aspect enables the tracking of changes and trends over time. The CAS framework provides a lens to understand emergent behaviors and non-linear interactions in the educational environment.[12,14–16]

Setting and Participants

The study was conducted at the College of Medicine, Alfaisal University. TBL implementation began in 2013, with assessment methods evolving from scantrons to clickers, and finally to ExamSoft in 2018.[16] The study focused on six academic years from 2018–2019 to 2023–2024, coinciding with the use of ExamSoft.

For the quantitative analysis, a total of 1635 first-year medical students across six cohorts (annual range: 241–304, M = 272.5, SD = 24.8) were considered. Students who met the inclusion criteria had full registration for all blocks of the first-year medical program and attended and completed all year 1 blocks, each featuring weekly TBL sessions. Those who missed any block during the academic year or dropped any TBL session in any block of year 1 were excluded.

This selection process ensured consistency in the longitudinal data analysis by including only those students who had complete data for all blocks throughout the academic year.

For the qualitative component, two groups of participants were involved:

1. Students: 30 students participated in the annual focus group discussions. Convenience sampling was used to recruit students for the focus group discussion. An email was sent to all students who had experienced TBL in their first year of medical school. Out of the 94 students who responded and showed interest, 30 respondents were randomly selected. Informed consent was obtained from all selected participants before their involvement in the focus group discussions.

2. Faculty: 15 faculty members participated in the focus group discussions. These faculty members were selected based on their representation of basic science subjects taught in year 1, active involvement in TBL implementation, and consent to participate in the focus group discussions.

This selection process ensured that the qualitative data captured perspectives from faculty members directly involved in the TBL process across various basic science disciplines in the first-year curriculum.

Data Collection

Quantitative data included Individual Readiness Assurance Test (i-RAT), Team Readiness Assurance Test (t-RAT), and overall TBL scores collected using ExamSoft, a comprehensive digital assessment platform. ExamSoft allows secure, computer-based testing and provides detailed performance analytics, enabling efficient collection and analysis of student performance data across various assessment types. To address missing data and dropouts, only students who completed all blocks of year one was included in the quantitative analysis.

Qualitative data was gathered through two primary methods:

a) Post-TBL Reflection Sessions: After each TBL session, faculty members participated in structured reflection sessions using Rolfe's model of reflection (What? So what? Now what?).[17] This structured approach allowed faculty members to describe their experiences, explore the significance of events, and consider next steps in the TBL process. Responses were recorded through written notes, providing immediate, context-specific insights into the TBL process and its outcomes.

b) Focus Group Discussions: Focus group discussions were conducted with 30 students (n=30) and 15 faculty members (n=15) involved in the TBL process. Focus group discussions were guided by a semi-structured discussion guide, designed to explore themes related to TBL implementation and its long-term impact. The guide covered topics such as experiences and perspectives of students and faculty involved in the TBL process, and the long-term impacts of TBL implementation. Example questions included "How has TBL affected your learning/teaching approach?", "What changes have you observed in student engagement since implementing TBL?", and "How has TBL influenced your long-

term educational experience?". Each session lasted approximately one hour, allowing for in-depth exploration of participants' experiences and perspectives.

This approach leverages the strengths of immediate reflection and retrospective discussion, aligning with the CAS framework by capturing real-time adaptations and emergent behaviors and broader systemic changes.

Data Analysis

Quantitative analysis involved calculating mean grades for i-RAT, t-RAT, and TBL for the first (Foundation) and last (Renal) block of each year, based on a pseudo pre-and post-test model. The percentage of students moving from the lowest quartile in the Foundation block to the fourth quartile in the Renal block was determined to identify improvements. Comparative analyses and quartile analyses were performed across the six academic years using the Microsoft Excel add-on package.

Qualitative data underwent thematic analysis aligned with CAS principles. The analysis process included:

1. Familiarization with the data through multiple readings of transcripts
2. Generation of initial codes
3. Searching for themes
4. Reviewing and refining themes
5. Defining and naming themes
6. Producing the report

Findings from quantitative and qualitative analyses were then integrated to provide a comprehensive understanding of TBL's impact within the CAS framework.

Ethical Considerations

The study was approved by the Institutional Review Board of Alfaisal University (IRB-19109), and all participants provided written informed consent before participation.

TBL Implementation Process

The implementation of TBL at our institution was a dynamic process that embraced the complexity and emergent nature of the educational system. Rather than unfolding in distinct phases, the following components were implemented simultaneously:

Adaptive Evolution of TBL

Initial Hybrid Model

We began with a blend of traditional lectures and TBL sessions, allowing the system to adapt organically and reduce resistance.[18]

Curriculum adaptation: Initially, all TBL sessions covered learning objectives already addressed in lectures. However, from 2019 onwards, the curriculum committee approved the addition of learning objectives not yet covered by lectures. This decision led to TBL questions covering learning objectives from both the current week (70%) and the upcoming week (30%), demonstrating the system's ability to self-organize and adapt based on observed outcomes.[19–21]

Core TBL Components

We implemented core TBL elements: pre-TBL preparation materials, Individual Readiness Assurance Tests (i-RATs), Team Readiness Assurance Tests (t-RATs), faculty-led discussions, and application exercises.[1,3–5]

This approach leveraged the emergent behaviors of student teams and faculty, fostering non-linear interactions and self-organization within the educational environment.[19,21]

Continuous Feedback and Adaptation

We established a framework for continuous improvement, including pre-TBL planning meetings, and reflective post-TBL meetings using the Rolfe model.[2,5,17] This approach created feedback loops characteristic of CAS, enabling the system to learn and evolve over time.[18,21]

Results

Quantitative Findings

Calculation of Mean Scores

Mean grades were calculated for i-RAT, t-RAT, and overall TBL scores for both the Foundation and Renal blocks. This calculation was performed for each academic year and across the six-year period.

In Pseudo Pre-and Post-Test model, the Foundation block scores were used as a baseline (pre-test) while the Renal block scores were used as the outcome measure (post-test). This model allowed for the assessment of improvement in student performance over each academic year.

Students were categorized into quartiles based on their performance in the Foundation block. The percentage of students who moved from the lowest quartile in the Foundation block to the fourth (highest) quartile in the Renal block was calculated.

This analysis aimed to identify significant improvements in learning and grades, particularly among initially lower-performing students.

Overall TBL Performance

The mean i-RAT score for the Foundation block over the six years was 5.83 and the corresponding value for the renal block was 6.06. The mean percentage i-RAT change between the two blocks is 4%. The composite TBL score shows an increase of 5% between these blocks as seen in Table 1.

The data consistently show improvement in mean scores from the Foundation block to the Renal block each year, indicating enhanced performance as students progressed through the academic year. This improvement suggests that TBL fosters continuous learning and skill development throughout the course.

Comparison of I-RAT vs TBL Scores

I-RAT Scores

The average mean i-RAT score improved from 5.83 in the Foundation block to 6.06 in the Renal block, representing a 4% increase [t Stat = −0.53095, p = 0.303523].

Table 1 Mean Score for the Different TBL Domains for the Two Blocks Over the Six-Year Period

Academic Year	n	Foundation Block			Renal Block		
		i-RAT	t-RAT	TBL	i-RAT	t-RAT	TBL
2023–2024	241	5.58	9.50	7.14	5.61	10.00	7.37
2022–2023	304	6.01	9.50	7.40	6.63	10.00	7.98
2021–2022	277	6.72	9.50	7.83	6.10	10.00	7.66
2020–2021	284	6.35	9.05	7.43	6.49	10.00	7.90
2019–2020	250	4.09	8.24	5.74	5.32	9.58	6.91
2018–2019	248	6.26	9.50	7.55	6.24	9.82	7.31
Mean		5.83	9.22	7.18	6.06	9.90	7.52
Percentage change in mean		0.04	0.07	0.05			

TBL Score

The average mean TBL score showed a greater improvement, increasing from 7.18 in the Foundation block to 7.52 in the Renal block, a 5% increase [t Stat = −0.97871, p = 0.175403].

These results demonstrate that while individual performance improved, the collaborative nature of TBL led to even greater enhancements in team performance. This finding underscores the effectiveness of TBL in fostering collaborative learning and highlights its potential to develop crucial teamwork skills essential for future medical professionals.

Quartile Analysis

To further identify pockets of qualitative improvement among students the percentage of students moving from the lower quartile in the foundation block to the fourth quartile in the renal block. Although the difference in student movement is not statistically significant, for at least three years [*] more students moved in the positive direction. The data for the past 6 years is shown in Figure 2.

This finding is particularly significant as it suggests that TBL was especially effective in improving the performance of initially lower-performing students. This demonstrates TBL's potential as an inclusive pedagogical approach that can help bridge performance gaps and promote equity in medical education.

While the quantitative data provides evidence for the effectiveness of TBL in improving student performance, our qualitative analysis offers deeper insights into the mechanisms and experiences underlying these improvements. The following themes emerged from our qualitative data, aligning closely with the principles of CAS theory.

Qualitative Insights

Emergent Themes Aligned with CAS Principles

Our qualitative analysis revealed that it matches with the principles of CAS during our analysis. These themes offer insights into the changes we observed.

Adaptive Implementation

Introducing hybrid TBL gradually proved to be effective in managing the challenges of educational change. This theme corresponds to the longitudinal improvement in TBL scores showing how the system adapted and improved over time.

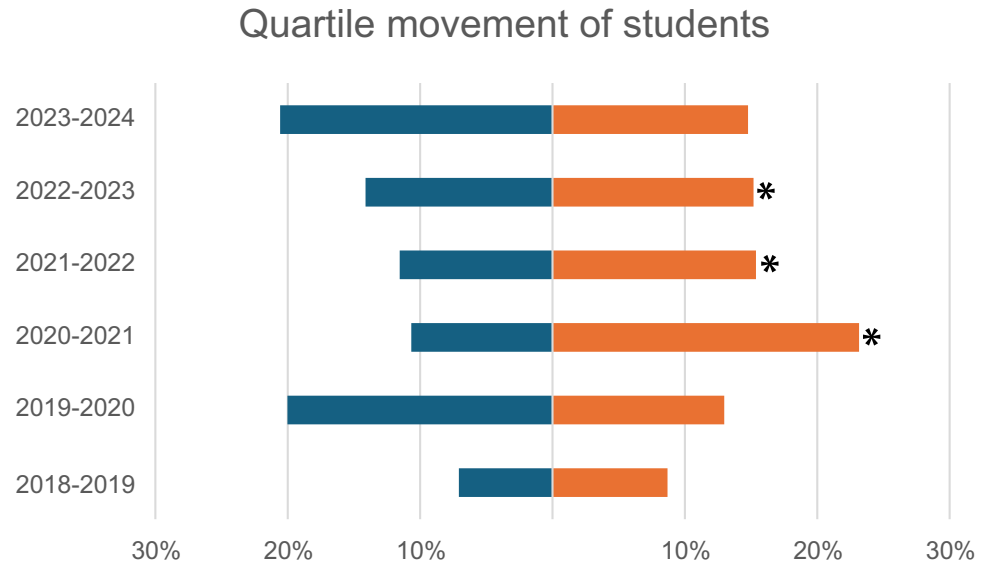

Figure 2 Quartile movement of students across academic years (2018–2024). The chart displays the percentage of students moving from the fourth (lowest) to the first (highest) quartile (dark blue bars) and from the first to the fourth quartile (Orange bars) for each academic year. Asterisks (*) indicate statistically significant differences ($p < 0.05$) between the two movements for the respective academic years.

According to one faculty member "The gradual introduction of TBL allowed us to adjust slowly and address challenges while enhancing our approaches step by step".

Emergent Outcomes

TBL sessions fostered the development of critical thinking and communication skills, exemplifying how local behaviors can lead to global system properties. This emergence of higher-order skills corresponds with the significant improvements in both i-RAT and t-RAT scores. A student remarked, "I found myself thinking more deeply about clinical scenarios and articulating my thoughts more clearly".

Self-Organization

Both faculty and students reported increased engagement and participation, including contributions from previously hesitant students. This self-organizing behavior supports the quantitative finding that students moved from the lowest to the highest quartile in three academic years as shown by asterisk in Figure 2. A faculty observer noted, "Teams naturally developed their own problem-solving strategies, with quieter students often providing crucial insights".

Positive Feedback Loops

The Immediate Feedback Assessment Technique (IF-AT) encouraged positive reinforcement loops, shaping system behavior and adaptation. This qualitative observation explains the consistent improvement in scores from the Foundation to the Renal block each year. As one student mentioned, "Getting instant feedback during t-RATs allowed us to correct our mistakes away boosting our self-assurance and performance".

Depth of Learning

TBL facilitated a shift from rote memorization to applied knowledge, demonstrating the CAS principle of emergence. This deeper learning approach is reflected in the substantial improvement in t-RAT scores, indicating enhanced collaborative problem-solving skills. A faculty member observed, "Students began to approach clinical problems with a more holistic perspective, integrating basic sciences with clinical reasoning".

Challenges and Adaptation

The implementation encountered initial opposition and group dynamics issues, which were subsequently adapted to, resonating with the concept of non-linear dynamics in CAS theory. This adaptability is evident in the gradual upward trend in overall TBL scores over the six-year period. One student shared their experience:

> Initially I had doubts about working in a team as it was not a team of my own choice. My friends were not in my team, and I was frustrated on this, but eventually I recognized its importance in getting us ready for team-based healthcare.

Discussion

Interpretation of Quantitative Results

Our analysis indicates some enhancements, in both i-RAT and t-RAT scores following implementation of TBL. Although these improvements are not considered significant, they offer perspectives for shaping upcoming curriculum development enhancements and align with the principles of CAS in education.[6–10] Additional research involving larger sample size or longer observation periods could be necessary to validate the statistical relevance of these enhancements.

The analysis of student quartile movement shows encouraging patterns in the application of TBL. Over three years, there is an increase in the number of students moving positively between quartiles, especially from the lower quartile during the Foundation block to the fourth in the Renal block. The visual representation of this trend as seen in Figure 2 over six years indicates that TBL could be particularly successful in boosting the performance of students who initially struggle. While not statistically significant this pattern hints at TBLs potential as a teaching method that can bridge performance gaps and promote equity in medical education. The average upward movement across quartiles, although not precisely quantified, further supports the broader positive impact of TBL on student performance. These

discoveries offer insights into how TBL enhances student achievement and encourages upward mobility among students.

Interpretation of Qualitative Insights

The emergent themes from our qualitative analysis show how the TBL implementation is in alignment with CAS principles. This adaptive implementation coupled with the observed self-organization and emergent outcomes, underlines the success of using a CAS informed strategy for educational change.

Alignment with CAS Principles

Adaptive Approach and Feedback Loops:

The continuous cycles of implementation, assessment, and refinement created robust feedback loops, which is a hallmark of CAS. These feedback loops operated at multiple levels - within individual TBL sessions, across courses, and throughout the curriculum - demonstrating the nested nature of the educational system. The improvements observed both within and across academic years further support the CAS concept. Our study uncovered the emergence of new behaviors and educational techniques among students and faculty, which is a significant feature of CAS.[6,8,18–20] For example, we noticed students devising problem solving methods within their teams displaying self-organization. This emergent behavior was noticeable, in the way reserved and quieter students expressed themselves and offered perspectives during team conversations.

Emergence and Self-Organization

While our quantitative data does not directly measure emergent behaviors, the improvement in average TBL scores compared to average i-RAT scores could suggest the emergence of effective team dynamics and collaborative learning strategies.[18]

Non-Linearity and Adaptation

The different rates of improvement between i-RAT (4%) and TBL (5%) scores hint at the non-linear nature of learning in this system. This difference, although small, may indicate that team-based learning is having a slightly stronger effect on performance improvement. The implementation process was iterative and responsive to feedback.[15,19]

Feedback Loops and Nested Systems

The comparison between Foundation Block and Renal Block average TBL scores provides a feedback loop that can inform future curriculum decisions. While the improvements are not statistically significant, they offer a starting point for further investigation and potential adjustments to the TBL implementation. The continuous cycles of implementation, assessment, and refinement created robust feedback loops, another hallmark of CAS. These loops operated at multiple levels within individual TBL sessions, across courses, and throughout the curriculum demonstrating the nested nature of our educational system.[10,15,21] The improvements observed both within and across academic years further support this CAS concept.

Recommendations for Other Institutions

Based on our experience, we offer the following recommendations for institutions considering CAS-informed educational innovations:

1. Embrace the complexity of the process and not try to control every aspect of the educational process. Acknowledge the complexities of learning environments. Be ready to adjust your methods based on the emergent behaviors.

2. Foster Multiple Feedback Loops: Create feedback channels to gather input from all agents involved. This could involve conducting surveys, hosting group discussions, and analyzing student performance data. Having multiple feedback sources will help the system adapt effectively.

3. Promote Self-organization: Promote self-organization among students and faculty members by encouraging them to produce strategies for utilizing educational approaches. This may include student led study sessions, faculty collaboration groups or teams focused on innovation.

4. Adopt an Iterative Approach: Make changes slowly and gradually. Be ready to adjust as needed. Sometimes multiple adjustments are needed. Be flexible, so the system can adapt easily and smoothly resulting in a reduction in resistance to change.

5. Develop CAS-Informed Research Methods: Given the challenges of capturing the full complexity of CAS in education, we recommend developing research methods that can account for non-linear relationships and emergent behaviors. This might include mixed-methods approaches, social network analysis, or agent-based modeling.[20]

Limitations and Generalizability

While our study provides valuable insights into the implementation of TBL using a CAS framework, several limitations should be acknowledged. Firstly, this study was conducted at a single institution, which may limit the generalizability of our findings to other medical education contexts. The unique characteristics of our institution, including its culture, resources, and student demographics, may have influenced the outcomes of TBL implementation.

Regarding generalizability, while we believe that the CAS-informed approach to TBL implementation can be valuable in various medical education settings, institutions should consider their unique contexts when adapting our approach. The principles of CAS theory suggest that each educational environment will have its distinctive dynamics and emergent behaviors.

The use of convenience sampling for focus groups may introduce self-selection bias, potentially overrepresenting students with strong opinions about TBL. While random selection from volunteers mitigated this, the qualitative data might not fully represent the entire student body's experiences.

Future research could address these limitations by conducting multi-institutional studies or by implementing similar CAS-informed TBL approaches in varied educational settings. This would provide a clearer apprehension of how CAS principles can guide educational improvements across different contexts.

Conclusion

Our research shows the value of using CAS principles which could enhance the implementation of TBL in medical education. Although the quantitative improvements were minor, the qualitative insights uncover emerging behaviors and adaptive processes that contribute to a more resilient and effective educational model. Embracing complexity and nurturing adaptability enables institutions to establish responsive learning environments that equip students better for the complexities of contemporary healthcare.

Data Sharing Statement

Raw data was generated at Alfaisal University. Derived data supporting the findings of this study are available from the corresponding author SQ upon request.

Acknowledgment

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Disclosure

The authors report that there are no competing interests to declare.

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