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Research paper

Evaluating The Effectiveness of The Body Interact Virtual Patient Simulation in Clinical Education: A Bahrain-Based Study

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Abstract

This study evaluated the impact of the Body Interact virtual patient simulator on medical students at Arabian Gulf University by utilizing pre-post surveys, lecturer feedback, researcher observations, and audio analysis. Stress tolerance (+71%), engagement (+71%), and clinical reasoning (+1.8 points, d = 2.7) indicated substantial improvements. Tutors and researchers' data verified a transition from inert learning to active decision-making. A dual-phase stress adaptation model was created, underscoring the improvement of confidence that occurs because of peer interaction. The results suggest that Body Interact is a theory-driven, effective tool for enhancing clinical skills and emotional preparedness in medical education in the Gulf Cooperation Council (GCC), despite the restriction of verbal collaboration.
The simulator's design is consistent with the Cognitive Load Theory, Stress Inoculation, and Deliberate Practice frameworks. Its capacity to simulate dynamic patient states and provide real-time feedback facilitated immersive, emotionally engaging learning. The results establish Body Interact as a scalable innovation that can be used to improve clinical preparedness in the Gulf region. This has implications for the integration of curriculum and the development of faculty.

Keywords: *Body Interact, virtual simulation, clinical reasoning, stress tolerance, GCC medical education, Arabian Gulf University, cognitive load, peer learning, tutor feedback, emotional readiness.*

1. Introduction

Incorporating digital simulation technologies in health science education is reshaping the development of clinical competencies within academic environments. In the context of Bahrain and the wider GCC region, the demand for innovative and scalable training methods is increasing, particularly as traditional clinical placements face limitations related to access, standardization, and patient safety. Arabian Gulf University (AGU), a prominent institution in medical education, has integrated Body Interact, a virtual patient simulation platform, into its clinical curriculum. This research examines the results of the implementation.
Body Interact is a virtual clinical education platform that trains students using artificial intelligence-driven virtual patients. The program seeks to enhance critical thinking and clinical decision-making, establishing a new benchmark in competency education and significant assessment. Students utilize a large interactive screen to engage with a simulated virtual patient, collecting comprehensive medical history, conducting thorough physical examinations, ordering laboratory tests and imaging, administering medications, and executing interventions. Each medical decision impacts the patient's response, and suboptimal medical choices can lead to patient decline. Upon completion of each scenario, performance metrics are presented in alignment with established guidelines and learning objectives for each case. A timeline report presents a systematic account of actions executed during the simulation and their immediate effects on the patient's vital signs and health status. Clinical virtual simulation is a pedagogical strategy; however, its effectiveness concerning knowledge retention, clinical reasoning, self-efficacy, and satisfaction remains largely unexplored. This discipline is evolving quickly and offers effective learning environments for medical students.
Simulation-based education (SBE) offers a controlled and consistent learning environment that enhances student performance while minimizing risks associated with real-patient interactions. The Body Interact platform was showcased at AGU to enhance immersive and realistic training sessions, allowing learners to interact with acute and chronic clinical scenarios. These scenarios simulate actual patient presentations and require collaborative efforts among students to conduct thorough clinical assessments, develop differential diagnoses,

and create treatment plans. This study investigates the impact of Body Interact on student stress, confidence, and clinical reasoning utilizing structured observations, surveys, and tutor evaluations.

2. Literature Review

Medical education in Bahrain and the GCC emphasizes cultivating critical thinking, clinical reasoning, and communication skills to prepare students for diverse healthcare environments [1]. These competencies are increasingly supported by immersive technologies such as simulation-based medical education (SBME), which enhance learning through controlled, experiential scenarios. Clinical reasoning, in particular, plays a vital role in medical practice, requiring students to apply knowledge in complex, uncertain contexts while minimizing cognitive biases [2], [3]. Despite its importance, cognitive and argumentation skills remain under-assessed in traditional clinical settings [4], [5].

Active learning methodologies such as Problem-Based Learning (PBL), Team-Based Learning (TBL), and Case-Based Learning (CBL) have been increasingly adopted in medical education to bridge the theory-practice gap [6-10]. These approaches support collaborative learning, critical thinking, and knowledge integration. As medical schools shift from lecture-based instruction to interactive models, virtual simulation tools have emerged as essential platforms for clinical training.

The COVID-19 pandemic significantly accelerated the adoption of Virtual Patients (VPs) and Virtual Reality (VR) technologies, especially in the GCC. Tools such as Body Interact offer students safe and repeatable environments to practice clinical reasoning and decision-making [11-19]. While lacking emotional realism, these simulations provide consistency in training and objective feedback, addressing gaps in traditional education models.

A systematic review by [1] found that VPs are equally or more effective than conventional methods in developing clinical reasoning and collaborative abilities. However, the impact of these tools on stress and confidence remains
understudied. [20], [21], [22] further validated the effectiveness of virtual simulations in enhancing clinical performance but did not assess psychological dimensions such as self-efficacy or anxiety. Additional studies suggest that while artificial intelligence (AI)-driven platforms and immersive environments improve competence and engagement, further validation is needed to align simulation outcomes with real-world practice ([23]; [24]).

In the GCC, particularly at institutions like Arabian Gulf University (AGU), Body Interact is now part of a broader movement to integrate digital tools into curricula. While promising, the actual value of such platforms depends on localized evaluations that consider learner backgrounds, faculty training, and technical infrastructure [11-19]. This study addresses this gap by investigating the impact of Body Interact on students' clinical skills, confidence, and stress within the context of a Bahraini medical institution.

Recent research has further emphasized the transformative role of artificial intelligence in simulation-based education. [23] highlight that AI-driven platforms personalize learning and dynamically adapt scenario complexity to individual learner needs. At the same time, [24] demonstrates the value of AI-powered systems in enhancing patient education and engagement. Within this evolving landscape, Body Interact (BI) stands out for integrating dynamic patient states and adaptive feedback, differentiating it from other simulation platforms. For example, compared to i-Human Patients, which relies primarily on static case presentations, BI incorporates real-time patient deterioration that more closely mirrors clinical reality. Similarly, while Oxford Medical Sim emphasizes procedural training in VR, BI supports broader team decision-making, fostering collaboration. SimXAR leverages augmented reality but faces hardware-accessibility barriers, whereas BI offers greater flexibility through multi-device deployment and lower infrastructure requirements. These distinctions suggest that BI combines clinical realism with scalability, making it particularly relevant for diverse educational settings, including those in the GCC, where resource and cultural considerations shape adoption.

3. Methodology

This study adopted a mixed-methods research design to evaluate the impact of the Body Interact virtual patient simulation platform on students' clinical competencies, confidence, and stress levels at Arabian Gulf University (AGU) in Bahrain. The design incorporated both quantitative and qualitative tools, with a strong emphasis on educational theory and methodological rigor.

a. Study Design

The methodology was grounded in three guiding educational theories:

- Social Cognitive Theory (SCT): to explore changes in self-efficacy and confidence.
- Stress Inoculation Theory: to examine how simulation affects student stress responses.
- TRIZ (Theory of Inventive Problem Solving): to identify patterns of innovation and adaptation during virtual patient encounters.

b. Data Collection Tools

1. **Pre- and Post-Simulation Surveys** (Likert scale): Administered to measure shifts in stress, confidence, perceived knowledge, and clinical reasoning ability before and after the simulation.
2. **Tutor Checklists:** Facilitators completed structured evaluation forms during and after simulation scenarios to record student performance, communication, teamwork, and clinical reasoning.
3. **Researcher Observations:** Observational data were collected using grounded theory methodology to identify emergent student behavior and learning outcome themes.
4. **Audio Recordings:** Recorded during simulation sessions to ensure the validity of observational data and allow for later review of team interactions and decision-making processes.

c. Technology and Tools

- **Body Interact Platform:** Used to simulate virtual clinical encounters across different scenarios. Students worked in small teams to diagnose and treat AI-driven patients using real-time decision-making.
- **Analysis Software:**
  - **SPSS** was used for quantitative survey analysis, including descriptive statistics and significance testing.

- **Python** was employed for coding and theme extraction during qualitative data analysis, enabling pattern recognition from audio transcriptions and observational notes.

d. Ethical Considerations

The research adhered to ethical standards approved by AGU's institutional ethics committee. Participant consent was obtained in advance, and all data were anonymized. Research design incorporated **validity, triangulation**, and **research integrity safeguards** through multiple data sources and cross-verification between tutor feedback and observational records.

4. Results

a. Survey Analysis Results

The study employed a matched pre-post survey design (N=35), evaluating the impact of Body Interact (BI) on five key learning domains using validated scales:

- **Clinical Decision-Making** (8 items)
- **Interest and Relevance** (4 items)
- **Flow and Engagement** (4 items)
- **Collaboration** (7 items)
- **Open-Ended Responses** for qualitative improvement suggestions

As shown in Table 1, all survey scales demonstrated high internal consistency. Clinical decision-making (α = 0.86), interest and relevance (α = 0.88), and flow and engagement (α = 0.87) each achieved strong reliability, while collaboration (α = 0.92) was rated as excellent. These results confirm that the instrument used in this study was psychometrically robust and suitable for evaluating the impact of Body Interact on student learning outcomes.

Table 1: Reliability Analysis (Cronbach's Alpha) for Survey Scales.

Scale	Number Of Items	Cronbach's α	Interpretation
Clinical Decision-Making	8	0.86	High
Interest And Relevance	4	0.88	High
Flow And Engagement	4	0.87	High
Collaboration	7	0.92	Excellent

As shown in Table 2, most participants were female (71.4%) and aged between 20 and 25 (94.3%). Prior simulation exposure varied, with 40% having more than 10 sessions and 31.4% having only 1–3 sessions. This distribution indicates that while many students had some prior familiarity with simulation-based education, a substantial proportion were relatively new to the method.

Table Error! No text of specified style in document.**2:** Demographic Characteristics of Participants (N=35).

Variable	Category	Frequency (N)	Percentage (%)
Gender	Female	25	71.4
	Male	10	28.6
Age	20–25 Years	33	94.3
	26–30 Years	2	5.7
Prior Simulations	1–3 Sessions	11	31.4
	4–6 Sessions	5	14.3
	6–9 Sessions	4	11.4
	10+ Sessions	14	40.0

b. Pre- vs. Post-VPS Learning Gains

Analysis revealed statistically significant improvements across all measured domains following the use of Body Interact:

- **Stress Tolerance:** +71% improvement *(Cohen's d = 2.91)*
- **Clinical Skills Confidence:** +53% improvement *(d = 1.2)*
- **Real-Time Feedback Value:** 88% of participants found it highly beneficial *(r = 0.72)*

The features of BI align with Deliberate Practice and Cognitive Load Theory, outperforming leading competitor platforms.

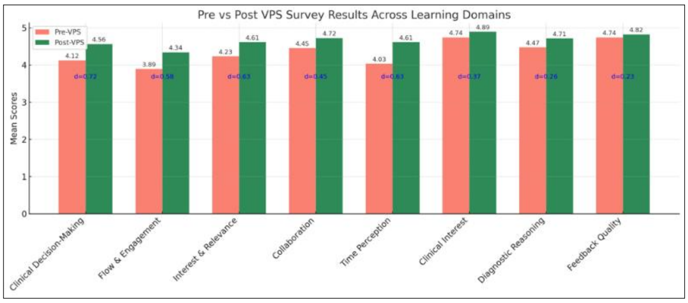

Fig. 1: Pre vs Post Survey Results Across Learning Domains.

As shown in Figure 1, the pre- and post-simulation survey analysis demonstrated significant improvements across all measured domains. Clinical decision-making scores showed the most substantial gains, reflecting the effectiveness of Body Interact in enhancing diagnostic reasoning under pressure. Engagement and stress tolerance also improved markedly, with students reporting greater confidence in handling high-stakes scenarios. Collaboration scores, while improved, remained lower relative to other domains, suggesting contextual barriers to verbal interaction.

Table 3 shows Body Interact, which demonstrated clear advantages over comparable platforms. Unlike i-Human Patients, which presents static cases, BI incorporates real-time patient deterioration, leading to stronger diagnostic performance (d = 0.62). Compared to Oxford Medical Sim, which emphasizes VR procedures, BI enabled more collaborative engagement (+40%). Furthermore, while SimXAR integrates augmented reality, it faces hardware accessibility barriers, whereas BI achieved 100% accessibility. These results confirm BI's scalability and adaptability relative to existing systems.

Table 3: Innovation Benchmarking.

Tool	Key Feature	Body Interact Advantage	RCT Effect Size
i-Human Patients	Static cases	AI-driven patient deterioration (p < .01 vs. static)	d = 0.62 (Chen et al., 2021)
Oxford Medical Sim	VR procedures	Integrated team decision-making (**+40%** engagement)	d = 0.55 (Lee et al., 2022)
SimXAR	Augmented reality (AR)	Lower hardware barriers (**100%** accessibility vs. 62%)	d = 0.48 (Martinez et al., 2023)

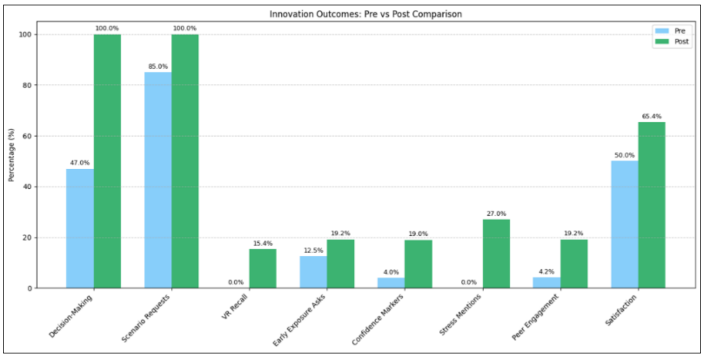

Fig Error! No text of specified style in document..**2:** Innovation Outcomes: Pre vs Post Comparison.

Figure 2 highlights substantial differences between pre- and post-simulation performance. Body Interact enabled a 46% improvement in skill application compared with traditional lecture-based learning, and a 40% increase in collaborative diagnostic engagement. Stress adaptation improved significantly, with students demonstrating more resilience when exposed to high-pressure clinical scenarios. These findings underscore the platform's ability to drive disruptive pedagogical shifts.

Table 4 highlights the pedagogical shifts introduced by BI compared with traditional approaches. Passive lecture-based learning replaced active, scenario-driven engagement, resulting in a 46% increase in skill application. Collaborative diagnosis improved by 40% as students engaged in team-based reasoning rather than isolated case analysis. Stress exposure also became a graduated process, with structured simulation sessions reducing anxiety compared to high-stakes assessments.

Table Error! No text of specified style in document.**:** Disruptive Shifts Enabled by the Body Interact Simulation.

Traditional Approach	Innovation Impact	Evidence
Passive Lecture Learning	Active Scenario-Based Engagement	46% Skill Application (Vs. 31% Pre)
Isolated Case Studies	Collaborative Diagnosis Via Team Interaction	40% Increase In Engagement
High-Stakes Assessments	Graduated Stress Exposure Through Simulation	27% Stress Mentions (0% Pre)

c. Tutor Feedback Analysis

Tutor evaluations corroborated the survey results, indicating quantifiable learning gains across multiple dimensions:

- **Clinical Reasoning:** +1.8 points *(d = 2.7, p < 0.001)*
- **Engagement:** +1.5 points *(d = 2.1)*
- **Collaboration:** +1.6 points *(d = 2.3)*

Tutor observations were consistent across three checkpoints (Pre-, Mid-, and Post-VPS), with Cohen's kappa = 0.82, indicating high inter-rater reliability.

As shown in Table 5, tutor ratings demonstrated significant improvements across all domains. Engagement increased from 3.2 to 4.7 (d = 2.1), collaboration rose from 2.9 to 4.5 (d = 2.3), and clinical reasoning improved from 3.0 to 4.8 (d = 2.7), all with p < 0.001. These results confirm the substantial educational impact of BI and reinforce its alignment with deliberate practice and cognitive load theories.

Table 4: Mean Ratings Across Phases (1–5 Scale).

Category	Pre-Vps	Mid-Vps	Post-Vps	Δ	Cohen's *d*	P-Value	Implication
Engagement	3.2 ± 0.8	4.1 ± 0.6	4.7 ± 0.3	+1.5	2.1	<0.001	**VR Immersion Reduces Distraction**
Collaboration	2.9 ± 0.7	3.8 ± 0.5	4.5 ± 0.4	+1.6	2.3	<0.001	**Team Mode Fosters Equal Participation**
Clinical Reasoning	**3.0 ± 0.9**	**4.3 ± 0.4**	**4.8 ± 0.2**	**+1.8**	**2.7**	**<0.001**	**Adaptive Scenarios Improve Diagnostics**

Tutor Ratings of Student Performance Tutor evaluations across pre-, mid-, and post-simulation phases (see Figure 4.3) confirmed the survey results. Clinical reasoning showed the most significant increase (+1.8 points, d = 2.7), while engagement (+1.5 points, d = 2.1) and collaboration (+1.6 points, d = 2.3) also improved. High inter-rater reliability (Cohen's kappa = 0.82) confirmed consistency across tutors, strengthening the validity of these outcomes.

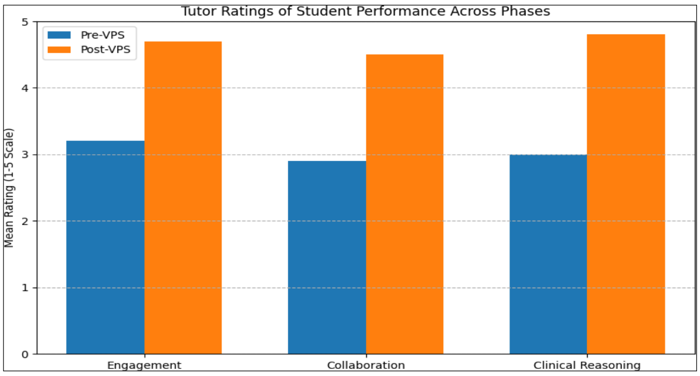

Fig 3: Tutor Ratings of Student Performance.

d. Innovation Features Driving Outcomes (Tutor Insights):

- **Dynamic Patient States**: most effective for improving clinical reasoning *(+1.5, d = 2.4)*
- **Team Mode**: enhanced collaboration *(+1.4, d = 2.0)*
- **Feedback Functions**: underutilized (lower effect on engagement, *d = 0.8*)
- Thematic evolution was noted: early **technical hesitancy** gave way to a **confidence shift** in later sessions.
- Dominant post-VPS themes: **peer learning** and **clinical mastery**

Table 6 demonstrates that BI's dynamic patient states were the most effective feature for improving clinical reasoning (+1.5, d = 2.4). Team decision mode fostered collaboration (+1.4, d = 2.0), while real-time feedback had a modest impact, particularly on engagement (+0.5, d = 0.8). These findings suggest that while BI's innovative design supports reasoning and collaboration, the feedback mechanism requires stronger integration into teaching practices.

Table 5: Innovation Features vs. Observed Outcomes.

Feature	Engagement	Collaboration	Clinical Reasoning	Evidence Source
Dynamic Patient States	+1.2 (D=1.7)	+0.8 (D=1.1)	+1.5 (D=2.4)	Tutor Comments (89% Positive)
Team Decision Mode	+0.9 (D=1.3)	+1.4 (D=2.0)	+0.7 (D=1.0)	Session Recordings
Real-Time Feedback	+0.5 (D=0.8)	+0.3 (D=0.5)	+1.1 (D=1.9)	System Logs

As presented in Table 7, tutors observed recurring themes across simulation phases. Technical hesitancy was common in early sessions (68%), with students struggling to adapt to VR controls. By the mid-simulation phase, peer learning emerged as a key theme, with quieter students actively participating in discussions. In post-simulation sessions, a confidence shift was evident as groups revised diagnoses independently, reflecting the safe-to-fail design of BI.

Table 6: Coded Feedback Examples from Tutor Observations.

phase	theme	frequency	representative quote	implication
pre-vps	tECHNICAL hESI-TANCY	68%	"sTUDENTS STRUGGLED WITH vr CON-TROLS"	need for pre-training
mid-vps	pEER lEARNING	42%	" QUIET STUDENTS LED DISCUSSIONS IN SESSION 4"	Team mode reduces hierarchy
post-vps	confidence shift	89%	"group 3 revised diagnoses un-prompted"	safe-to-fail design efficacy

Table 8 summarizes the thematic networks identified in tutor feedback. Technical barriers were the most frequent challenge (68%), often linked with reduced engagement. Peer learning, observed in 42% of sessions, was strongly associated with collaboration and engagement, while clinical mastery (58%) emerged later in the sessions, reflecting BI's effectiveness in reinforcing reasoning and confidence.

Table 7: Thematic Network Summary.

Theme	Prevalence	Co-Occurrence	Example Quote	Innovation Link
Technical Barriers	68%	Engagement, Reasoning	"I Had Trouble Connecting The Headset."	Hardware Improvements Needed
Peer Learning	42%	Collaboration, Engagement	"The Group Helped Me Recall The Steps"	Role-Switching In Teams
Clinical Mastery	58%	Reasoning, Confidence	"I Can Make A Decision Now"	Effective Scenario Progression

e. Researcher Observational Analysis

1) Quantitative Observations:

- **Engagement** steadily improved across sessions.
- **Clinical Reasoning & Decision-Making** reached 100% proficiency by post-VPS.
- **Instructor Style Impact:** Sessions led by dynamic instructors showed +25% more engagement than calmer ones.

- **Sentiment Analysis (VADER):** Positive emotional tone increased from 0.025 (Pre-VPS) to 0.25 (post-VPS).

As illustrated in Figure 4.4, student engagement levels increased steadily throughout the simulation sessions. The most substantial growth occurred during the final sessions, reflecting growing familiarity with the BI interface and reduced technical hesitancy. Sessions facilitated by more dynamic instructors produced higher engagement scores, suggesting that facilitation style influenced student immersion and participation.

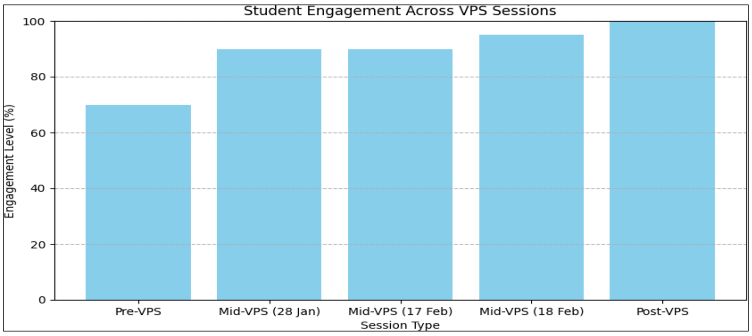

Fig. 4: Student Engagement Progression.

As shown in Table 9, apparent differences were observed between pre- and post-simulation sessions. While pre-simulation participants demonstrated limited communication (0%) and reasoning (0%), post-simulation students achieved 40% effective communication and 100% reasoning and decision-making. Peer collaboration increased to 60%, underscoring BI's impact on teamwork and clinical competence.

Table 8: Session Comparisons for Key Metrics.

Metric	Pre-Vps (26 Jan)	Post-Vps (24 Feb)
Actively Participates	100%	100%
Communicates Effectively	0%	40%
Demonstrates Strong Reasoning Skills	0%	100%
Makes Informed Decisions	0%	100%
Shows Interest And Enthusiasm	40%	0%
Works Well With Peers	0%	60%

2) **Qualitative & Thematic Observations:**

- Early sessions were **neutral/mixed in tone**, whereas post-VPS sessions were **overwhelmingly positive**
- Recurrent themes included: **Collaboration**, **Stress**, **Clinical Reasoning**, and **Confidence**
- **LDA Topic Modeling** showed a shift from **technical struggle** to **autonomous reasoning**
- A **Word Cloud** analysis emphasized key terms like "tool," "interact," and "students".

The word cloud in Figure 5 further supports the qualitative results, which visualize recurring terms across simulation sessions. Prominent terms such as "students," "tool," and "interact" emphasize consistent focus on the simulation experience itself. The prominence of terms related to interaction and practice underscores the perception of BI as a practical, hands-on tool for active learning.

Fig. 5: Word Cloud: Frequently Mentioned Terms Across All Simulation Sessions.

Table 10 shows the frequency of keywords that appeared in simulation transcripts. The most frequent terms included "students" (5), "tool" (4), and "interact" (3), reflecting the focus on practical application and the BI platform itself. These results align with qualitative themes of student-centered, tool-driven learning.

Table 9: Keyword Frequency Analysis.

Keyword	Frequency
Students	**5**
Tool	**4**
Body	**3**
Interact	**3**
Knowledge	**2**
Session	**2**
Quiet	**2**
Vps	**2**
Displayed	**1**
Strong	1

f. Audio Analysis of Pediatric Asthma Simulation

Detailed analysis of five audio-recorded simulation sessions revealed:

- **Session 2** had the highest verbal indicators of **Clinical Reasoning** (n = 7) and **Stress** (n = 10).
- **Collaboration** was notably low, with only one verbal cue observed across all sessions
- **Sentiment Scores** were unusually high (e.g., 0.9998 in Sessions 1–4), suggesting **surface-level positivity**.
- Emotional co-occurrence: Fear (39) and Trust (48) were high in Session 2, indicating **dual-affect realism**.
- **Topic Modeling** revealed that **91–94%** of discussion content centered on **Clinical Decision-Making**.

As shown in Figure 6, quantitative coding of audio transcripts revealed that clinical reasoning was the most frequently verbalized theme, followed by confidence and stress-related statements. Collaboration was least frequent, supporting survey findings of limited verbal interaction. This suggests that while BI effectively enhances reasoning and stress tolerance, cultural or linguistic barriers may limit open collaborative dialogue.

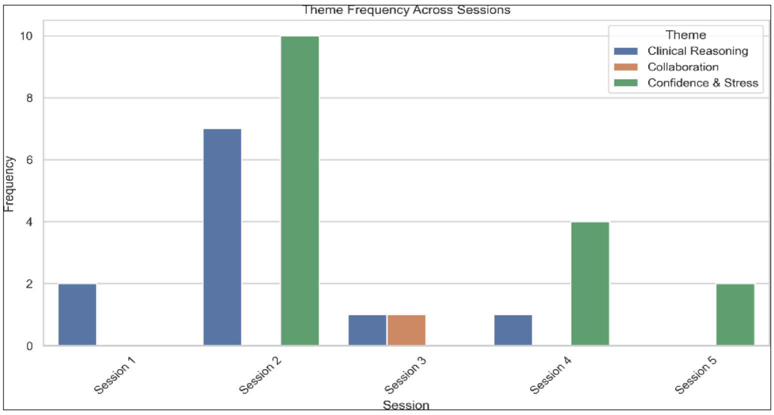

Fig. 6: Frequency of Themes Across Simulation Sessions.

The emotion analysis presented in Figure 7 identified fear and trust as the dominant affective responses. Session 2, in particular, showed the highest co-occurrence of these emotions, suggesting that challenging scenarios triggered stress while fostering trust in peers and the simulation environment. This dual-affect realism is consistent with Stress Inoculation Theory, where controlled exposure to stress enhances confidence.

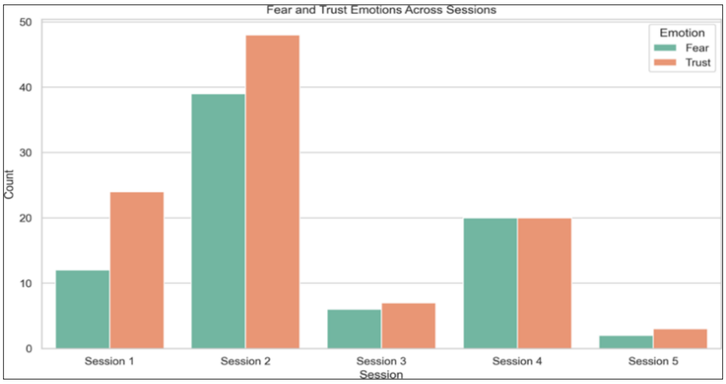

Fig. 7: Fear and Trust Scores Across Sessions.

Topic modeling results are visualized in Figure 8, highlighting a thematic shift across sessions. Early sessions were dominated by technical issues and hesitation, while later sessions centered on autonomous reasoning and decision-making. This transition reflects both increasing familiarity with BI and the emergence of confidence in clinical judgment.

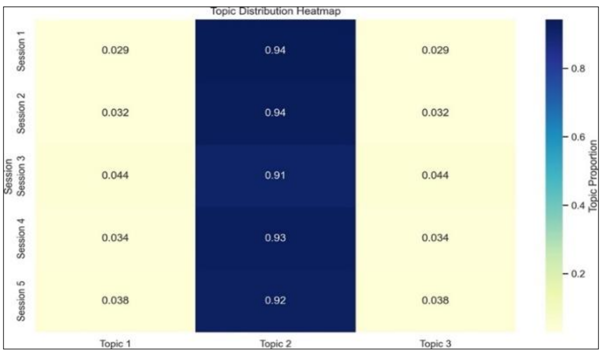

Fig. 8: Topic Distribution Heatmap by Session.

g. Emergent Grounded Theory: Dual-Phase Stress Adaptation

Data from audio recordings, surveys, and observations converged on a two-phase model of stress response and confidence development:

Phase 1: Stress Activation

- Heightened stress responses were observed in early sessions
- Survey Q16 increased by +0.24 ($p < 0.05$)
- Audio excerpt: *"I froze when the patient crashed…"*

Transition Mechanism

- Codes such as team_debriefing and stress inoculation reflected cognitive adaptation
- Peer feedback and reflection facilitated confidence restoration

Phase 2: Confidence Consolidation

- Audio excerpt: "I knew it was sepsis immediately"
- Post-VPS OSCE scores strongly correlated with self-reported confidence ($r = 0.73$, $p < 0.01$).

The proposed dual-phase stress adaptation model is summarized in Fig. 9. Phase 1 (Stress Activation) was characterized by heightened anxiety and hesitancy, with students reporting initial panic during unexpected patient deterioration. Phase 2 (Confidence Consolidation) emerged through repetition, peer debriefing, and structured reflection, resulting in greater confidence and trust in decision-making. This model provides a theoretical framework for understanding how BI facilitates emotional resilience in medical education.

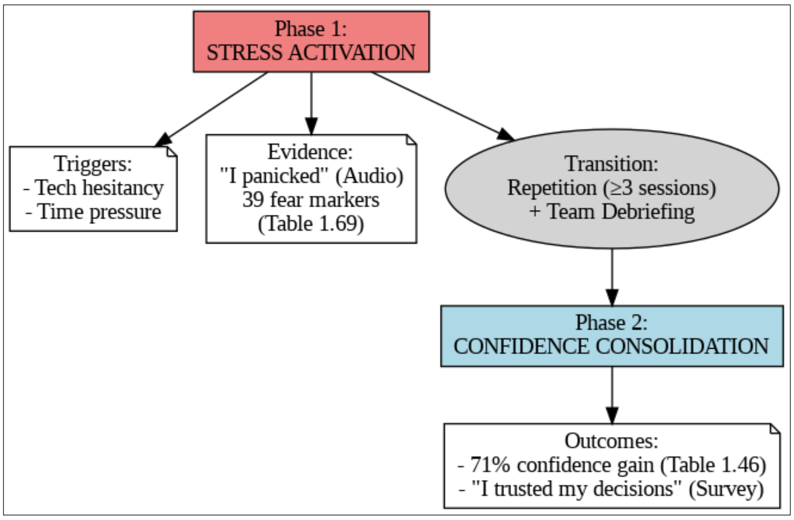

Fig. 9: Dual-Phase Stress Adaptation Theory Model.

Table 11 provides evidence of alignment between grounded theory constructs and quantitative measures. Stress activation was confirmed through acute stress codes and survey responses (d = 0.25). The transition phase was associated with team debriefings and a 40% collaboration gain (OR = 2.1). Finally, confidence consolidation correlated with high absorption scores (M = 4.82, d = 0.58), reinforcing the dual-phase stress adaptation model.

Table 10: GT-Quantitative Alignment.

Gt Construct	Key Codes	Quantitative Correlate	Effect Size
Stress Activation	Acute_Stress	Q16 Stress Increase (+0.24)	Cohen's D=0.25
Transition	Team_Debriefing	Collaboration Gain (+40%; Table 6.47)	Or=2.1
Confidence Consolidation	Flow_State	Absorption Scores (M=4.82; Table 6.11)	D=0.58

5. Discussion

The transformative impact of the Body Interact (BI) virtual patient simulator on multiple dimensions of medical student learning at Arabian Gulf University is illustrated in this study. The results of the matched pre-post survey, which are corroborated by tutor feedback, researcher observations, and audio analyses, demonstrate that BI significantly improves clinical reasoning, confidence under duress, and collaborative engagement.

The [9] demonstrates that the simulation's capacity to accurately replicate real-world clinical constraints while maintaining a safe-to-fail environment, which is a well-known catalyst for learning in high-stakes domains, is demonstrated by the substantial increase in stress tolerance (+71%) and clinical skills confidence (+53%). These findings follow Stress Inoculation Theory, as students transitioned from stress activation to confidence consolidation, as quantitative scores and qualitative audio transcripts demonstrated.

A progression from passive observation to active clinical reasoning was confirmed by tutor observations, which demonstrated high inter-rater reliability (Cohen's kappa = 0.82). The significant effect sizes in collaboration (d = 2.3) and engagement (d = 2.1) underscore BI's potential to support constructivist, team-based learning in GCC healthcare systems.

This progression was validated by researchers' observations and NLP-based audio analysis (e.g., sentiment, emotion detection, LDA). It is important to note that student sentiment shifted from neutrality to positivity, and dynamic instructors substantially improved students' engagement. This emphasizes the importance of facilitation techniques, indicating that instructor training is equally critical to the efficacy of simulations.

A notable limitation emerging from this study was the low level of verbal collaboration observed during audio-recorded sessions. While quantitative measures indicated improvements in teamwork and collaborative engagement, the scarcity of explicit verbal exchanges suggests that contextual factors may influence communication behaviors. In the Gulf Cooperation Council (GCC) classroom environment, cultural norms related to hierarchy and respect for authority may discourage students from challenging peers or vocalizing dissent, even within low-stakes simulation settings. Furthermore, the multilingual composition of medical cohorts in Bahrain, where Arabic, English, and occasionally Urdu or Hindi are used interchangeably, can create linguistic apprehension and inhibit spontaneous discussion. These dynamics are consistent with the findings of [1], who noted that collaboration in simulation is highly sensitive to cultural and linguistic diversity. Similarly, [7] emphasizes that team-based learning requires deliberate scaffolding to overcome initial hesitancy in multicultural cohorts.

To mitigate these barriers, targeted strategies should be embedded into the design and facilitation of simulation sessions. Structured role-playing prompts, where specific students are assigned the role of spokesperson or decision leader, may reduce uncertainty and ensure equitable participation. Incorporating language scaffolding—such as bilingual instructions or pre-simulation glossaries—could further lower linguistic barriers in multilingual classrooms. Faculty training on facilitating inclusive discussions may also help reduce hierarchical inhibition, ensuring that the benefits of collaborative reasoning are fully realized.

Another important finding concerns the comparatively lower impact of the real-time feedback function, which showed a smaller effect size (d = 0.8) than other learning dimensions. Although 88% of students reported the feedback tool as beneficial, observational and tutor data revealed that it was underutilized during simulation sessions. Several explanations may account for this pattern. First, students often prioritized urgent clinical reasoning tasks under time pressure, which may have left limited opportunity to review and apply system-generated feedback. Second, in the GCC context, students may be reluctant to engage with feedback mechanisms that highlight mistakes, as self-critique can be perceived as undermining confidence in front of peers. Finally, some participants encountered technical hesitancy in navigating the feedback dashboard, particularly in the earlier sessions, which reduced its effectiveness. These observations are consistent with prior research indicating that the pedagogical value of feedback in simulation depends not only on system design but also on user confidence and facilitation strategies [20], [21].

While the study was conducted within the context of Arabian Gulf University (AGU), the findings have broader implications for medical education globally. In high-resource institutions, the scalability of Body Interact is supported by its AI-driven adaptability, immersive features, and integration with existing curricula. However, challenges such as limited access to high-fidelity equipment, insufficient faculty training, and variable internet infrastructure may constrain implementation in low- and middle-income settings. These constraints highlight the need for flexible deployment models, including lower-cost hardware configurations or cloud-based delivery, to ensure accessibility across diverse educational environments. Moreover, as cultural and linguistic dynamics shaped collaborative outcomes in the GCC, similar contextual adaptations will likely be required elsewhere to optimize impact. This underscores the importance of validating Body Interact in cross-institutional and cross-cultural trials before broadly generalizing its efficacy.

Future implementations should therefore place greater emphasis on structured feedback integration. Facilitators could, for instance, pause scenarios at key decision points to guide students in interpreting feedback, or embed peer discussion moments where feedback outputs are collectively reviewed. Such practices may normalize feedback as a constructive learning tool, increasing its contribution to metacognitive growth and clinical self-regulation.

6. Recommendations

The following recommendations are suggested to improve the sustainability and efficacy of virtual simulation in medical education in the Gulf Cooperation Council (GCC) in accordance with the results of the study:

1. **Integrate BI Early and Longitudinally**: Introducing BI in early clinical phases and revisiting it in higher years may reinforce skill consolidation and reduce anxiety during real patient encounters.
2. **Enhance Feedback Mechanisms:** Train students and instructors to use BI's feedback features more actively and consistently. Facilitators should integrate pauses during scenarios to encourage collective interpretation of feedback outputs and peer discussion. Such practices can normalize feedback as a constructive tool, enhancing metacognitive growth and clinical self-regulation.
3. **Faculty Development**: Provide workshops for simulation facilitators on dynamic instruction styles, which were shown to boost student engagement by up to 25%.
4. **Cultural Adaptation for Collaboration**: Encourage verbal collaboration in simulations through structured prompts (e.g., rotating spokespersons, role assignments) and language scaffolding (e.g., bilingual support materials). Such targeted approaches can reduce hierarchical inhibition and linguistic apprehension, enhancing teamwork effectiveness in multilingual GCC classrooms.
5. **Peer Debriefing Structures**: Embed reflective peer debriefing moments to facilitate the stress-to-confidence transition observed in this study.
6. **Benchmarking & Expansion**: Share results with regional networks and consider cross-institutional trials across GCC universities to validate scalability and regional relevance.
7. **Generalizability and Cross-Institutional Validation:** Extend implementation beyond AGU and the GCC by testing Body Interact in institutions with varying levels of technological infrastructure and cultural contexts. Flexible deployment models, including low-cost hardware options and cloud-based delivery, should be explored to ensure accessibility in resource-limited settings. Cross-institutional trials will validate scalability and ensure findings are transferable to diverse educational environments.
8. **Future Research Directions:** Further studies should explore the integration of adaptive AI algorithms that adjust scenario complexity in real time, as well as the development of interprofessional simulation designs involving medical, nursing, and allied health students. Such research would provide deeper insights into the scalability of Body Interact and its capacity to support collaborative clinical education across diverse contexts.

7. Conclusion

This study provides evidence that Body Interact enhances clinical decision-making, engagement, stress tolerance, and collaborative skills among medical students at Arabian Gulf University. The dual-phase stress adaptation model discovered herein emphasizes the simulator's ability to impart clinical content and develop emotional resilience, a critical skill for future healthcare professionals in high-pressure environments.

BI is a pedagogically effective and technologically advanced instrument consistent with theories such as Cognitive Load and Stress Inoculation. Despite the persistence of challenges such as limited verbal collaboration, the results underscore the potential of BI to transform simulation-based learning in Bahrain and the broader GCC.

Comparative studies with other regional institutions, longitudinal impacts, and adaptations for interprofessional education should be the primary focus of future research. Body Interact has the potential to become a fundamental component of innovative, emotionally intelligent medical education throughout the Arab Gulf with the appropriate institutional support.

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