Simulation at the Frontier of the Zone of Proximal Development: A Test in Acute Care for Inexperienced Learners

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Abstract

Purpose

Vygotsky's zone of proximal development (ZPD) refers to the space between what learners have mastered and what they should master in the next developmental stage. Physicians' tasks are ZPD activities for medical students, with high-acuity tasks such as resuscitation representing activities at the ZPD's frontier. This type of task can be taught and assessed with simulation but may be demanding and stressful for students. Highly challenging simulation may lead to a negative simulated patient outcome and can affect the participant's emotional state, learning, and motivation. This study aimed to increase understanding of the psychosocial and educational impact of simulation at the frontier of the ZPD.

Method

The authors conducted 11 phenomenological interviews between September 2016 and May 2017, to describe medical students' experiences with a challenging residency-level simulation test of acute care competence at the start of the final undergraduate year at University Medical Center Utrecht. Interviews took place within 2 weeks after the participants' simulation experience. The authors analyzed transcripts using a modified Van Kaam method.

Results

Students experienced a significant amount of stress fueled by uncertainty about medical management, deterioration of critically ill simulated patients, and disappointment about their performance. Stress manifested mainly mentally, impeding cognitive function. Students reported that awareness of the practice setting, anticipation of poor performance, the debriefing, a safe environment, and the prospect of training opportunities regulated their emotional responses to stress. These stress-regulating factors turned stressful simulation into a motivating educational experience.

Conclusions

Simulation at the ZPD's frontier evoked stress and generated negative emotions. However, stress-regulating factors transformed this activity into a positive and motivating experience.

Vygotsky's zone of proximal development (ZPD)[1] is a widely cited concept in education. It refers to "the distance between the actual developmental level as determined by independent problem solving and the level of potential development … under [adequate] guidance…."[1] The ZPD is the variable space between what a learner has mastered and what they are not yet able to do and is determined by what an individual can sufficiently perceive as doable when assisted.[2] The ZPD does not simply refer to the amount of support a learner needs when acquiring a new skill but also to the steps needed to transition to the next developmental stage of capability.

While Vygotsky related the ZPD specifically to the age-related cognitive child development stages, the concept has been applied widely in all educational settings. In higher education, the ZPD has been linked to the concepts of constructive and destructive friction between teaching and learning.[3] A student's comfort zone is where he or she can perform tasks independently. When students are presented with teaching activities that invite them to leave this comfort zone—that is, when they can only complete an activity when they receive expert guidance—*constructive* friction is generated.[4,5] *Destructive* friction occurs when the gap between the comfort zone and the task is so large that the student cannot complete the activity (even with support) or when the gap is too small (instruction is redundant and might even hamper completion of the activity).[3,4]

Medical students who perform physicians' tasks are completing activities in their ZPD if guidance is provided. Complex medical responsibilities may be too difficult for the student to take on, leading to destructive friction, and can be viewed as activities at the far edge, or frontier, of the ZPD.

Acute care activities, for example, resuscitation of critically ill patients, exemplify how inexperienced learners may have to confront the ZPD frontier in a very visible fashion in medical education. Medical students can be trained for such high-acuity events and assessed with simulated clinical immersion.[6,7] Simulation training and assessment can be used at different stages of the medical educational continuum,[7–9] but to be educationally effective, the difficulty of the simulation task should be tailored to the developmental level of the participants,[10] pushing them beyond their current level of mastery, into the ZPD, to guide development in constructive friction. Simulation scenarios that are too demanding, that is, at the far edge of the ZPD, cause destructive friction and may

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The authors have informed the journal that they agree that both Fedde Groot and Gersten Jonker completed the intellectual and other work typical of the first author.

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be a waste of learning opportunities and resources. Moreover, at the frontier of the ZPD, poor participant performance is likely, leading to a negative simulated patient outcome. How such a negative outcome affects the participant's emotional state, learning, and motivation is not completely understood.

Simulation can induce physiologically measurable levels of stress.[11,12] Stress can also manifest at a mental level, imposing cognitive load and reducing a student's mental resources for learning.[13] The distress that arises from failing to manage a deteriorating patient likely adds to a student's cognitive load.[13] It is safe to state that working with simulated critically ill patients is stressful.[12,14–16]

Management of critically ill simulated patients occurs at the ZPD's frontier for most medical students and, to the greatest extent, for untrained students, such as those participating in a pretest.

A pretest is an assessment of a student's level of knowledge, skill, or competence before instruction and learning. Simulation pretesting can be a powerful tool to clarify the learning objectives of a course. A student can experience such a formative assessment as valuable and motivating.[17–19] However, pretesting that is too challenging and stressful and that results in poor performance could cause destructive friction and may demoralize the student. How to strike the right balance in simulation pretesting at the ZPD's frontier is unknown.

We undertook a study to answer the following question: How do untrained medical students experience the simulation of overly challenging cases? The aim of the study was to increase understanding of the psychosocial and educational impact of simulation at the edge of the ZPD. The goal was not only to gain knowledge about Vygotsky's ZPD in the context of simulation but also to provide insight in the use and effect of highly challenging pretests.

Method

We designed a qualitative phenomenological study to explore students' lived experience of simulations at the ZPD's edge. Phenomenology is a methodological approach within the interpretivist research paradigm that considers social reality to be formed by subjective human experiences and social contexts.[20,21] It aims to understand the social reality of a phenomenon by collecting firsthand accounts of the phenomenon and describing the common meaning of those experiences.[21–23] Phenomenology holds that the presented reality of a phenomenon is constructed from the subjects' conscious thoughts, feelings, and ideas about their experiences.[22]

Context

In an effort to ease the transition to postgraduate training, medical schools in the Netherlands have redesigned the sixth (the final) year into a "transitional year."[24] The transitional year includes dedicated elective tracks to enable students to develop early residency-level competence and a specialty preference.[24,25] The University Medical Center Utrecht introduced a multidisciplinary elective track in the transitional year aimed at providing students the opportunity to acquire acute care competence, preparing them for postgraduate training in anesthesiology, cardiology, emergency medicine, intensive care, or pulmonary medicine.[26,27] Students in this themed final-year program take multiple electives from these specialties. Another specific feature is a formative pretest of acute care competence. This junior residency-level test is meant to focus students on acute care elective entrustable professional activities (EPAs) that are objectives of the year ahead and to provide insight into the students' strengths and weaknesses at the outset of the track. The multimodal assessment measures knowledge, skills, clinical reasoning, and clinical performance in high-fidelity simulations of acute care settings. Students take a similar posttest at the end of the year to measure their individual development. All data are used both to provide feedback to students and for research purposes. The introduction of the pretest gave rise to the research question of this study.

The simulation pretest

The Simulation Center of Rijnstate Hospital, Velp, the Netherlands, hosted the simulation pretest, which took 3 and a half hours for groups of 4 students concurrently. Anesthesiologists, anesthetic nurses, and an anesthesiology resident, who were all EUSim-certified simulation facilitators,[28] ran the test. Every student took part in 3 simulations, each lasting approximately 12 minutes. Scenarios required acute care in emergency room and ward settings (e.g., anaphylaxis, postoperative hemorrhage, acute myocardial infarction). A nurse was present and acted on instruction of the student only. Using a scenario-specific checklist, an anesthesiologist assessed students from behind a one-way screen. The resident debriefed each student after the scenario in private, allowing the student to vent emotions and to ask questions about medical or technical aspects. Debriefing was nonevaluative, pinpointing positive performance and highlighting poor performance as learning opportunities. To adhere to simulation research reporting guidelines,[29] we have provided a detailed description of the simulation context, a typical scenario, and the assessor's checklist (see Supplemental Digital Appendix 1 at http://links.lww.com/ACADMED/A811).

Participants

Every 6 weeks, 2 to 6 final-year medical students enroll in the acute care themed final-year program on a rotational basis and start with the simulation pretest of acute care competence. During the study period, we approached all students who had taken the simulation pretest to participate in the interview study. Immediately after students had completed the simulations and were leaving the simulation center, a member of our team asked each of them to participate in our study. We invited the students after the simulation to avoid potential influence of study goal awareness on their lived experiences. Students received oral and written information and gave written informed consent. The Ethical Review Board of the Netherlands Association for Medical Education approved the study in May 2016.

Data collection

We gathered first-person accounts of lived experiences with the simulation pretest by single in-depth, face-to-face private interviews. Interviews were conducted in Dutch, and members of the research team translated into English the representative quotations from those interviews that appear in this research report.

We devised an interview guide with open-ended questions, following guidelines by Moustakas.[22] The interviewer asked the participant, after a prompt, to focus attention on the experience and to become aware of feelings and thoughts, to describe his or her lived experience thoroughly. The interviewer asked clarifying, probing questions to obtain thick descriptions. Next, the interviewer asked open-ended questions that followed the chronology of the simulation pretest experience. The interviewer evoked reflections on felt space and time, bodily sensations, and the relation to others and self to gain thick descriptions.[22] Next, the interviewer elicited factors that the participant perceived to affect the experience. All authors approved the interview guide (see Supplemental Digital Appendix 2 at http://links.lww.com/ACADMED/A811) before we piloted it on one student. Interviewing took place between September 2016 and May 2017, within 2 weeks after the participants' simulation experience. Concurrent analysis of interviews enriched questioning in subsequent iterations of data collection, and this process continued until we achieved theoretical sufficiency, that is, until we could categorize new data without the need for additional themes.

Our participation rate was 100%: The first 11 students we invited to participate all accepted. There were 4 male and 7 female participants with an interview duration of approximately 30 minutes.

Data analysis

A commercial agency transcribed the audiorecorded interviews verbatim.

Two authors (F.G., G.J.) analyzed the transcripts using a 9-step modified Van Kaam method.[22] After immersing themselves in the data by listening and reading, F.G. and G.J. carried out step 1, "horizonalization," individually by identifying each statement referring to the experience in each transcript. In step 2, reduction and elimination, the 2 researchers organized the horizons identified in step 1 into units of meaning, called constituent themes, and clustered these in steps 3 and 4 into invariant core themes of the experience, leading to individual textural descriptions (step 5). Participants checked these descriptions to verify that they portrayed their lived experience. In step 6, the 2 researchers sought the essence of the experience by recurrently engaging in critical dialogue and applying imaginative variation, looking at the transcripts and individual textural descriptions from various vantage points. Through reflection and discussion, the researchers interpreted accounts on a more abstract level, looking at implicit meanings, leading to an individual structural description of how the phenomenon was experienced (step 7). Finally, the researchers integrated individual descriptions into a collective one, called a composite textural description (step 8, see Supplemental Digital Appendix 3 at http://links.lww.com/ACADMED/A811). From that description, they synthesized a composite structural description that describes the universal essence of experiencing the phenomenon for the group of participants (step 9). Up to this point, the other authors were not involved in the data analysis.

We used the Journal Article Reporting Standards for Qualitative Research checklist to guide reporting of our research.[30]

Reflexivity

Adopting a phenomenological attitude, we aimed to better understand the phenomenon by exploring subjects' lived experiences open mindedly, suspending all judgments about what was significant until we had grounded the significance in the data.[22,31] To do this, we reflexively explicated our own experience with the phenomenon and our preexisting opinions about the phenomenon. Throughout the research process, we balanced awareness of these so-called preunderstandings with setting them aside.[31] The primary interviewer (F.G.) had observed the students during the simulations and led the informal debriefings after each simulation scenario. When F.G. was unavailable, another investigator (G.J.) acted as an observer during the simulation and conducted the interviews. Presence of the interviewer at the simulation served to establish rapport and allowed the interviewer to relate to the events.

F.G. was an anesthesiology resident at the time of this study and was unknown to the participants. As a certified simulation facilitator, F.G. was concerned that the simulation pretest would be too difficult. At the time of the study, G.J. was an anesthesiologist and coordinator of the acute care track in the transitional year that participants enrolled in. As such he had met with the students before this study began to explain the structure of the track and the pre- and posttests as a part of the track. G.J. had no role in the evaluation of students in the tests or during the year. G.J.'s acquaintance with the students seemed beneficial, and his role as coordinator did not negatively affect participants' willingness to express themselves. G.J. had limited personal experience as a simulation participant.

In the initial stage of analysis, participants established proximity of the individual textural description to their lived experience. In addition to describing the essence of experiencing the phenomenon, by staying close to individual stories, we interpreted the experiences to gain transferable understanding of the phenomenon, "dancing between positions"[31] of pure descriptive and interpretative hermeneutic phenomenology. Interpretation took place in intensive dialogues between F.G. and G.J., during which they assumed various roles such as educator, caregiver, simulation trainer, and exam candidate to understand meanings from different vantage points. The 2 researchers used these roles to address preunderstandings and reflect on what the data evoked in them.

Results

All participants agreed with the individual textural descriptions of their experience. We amalgamated the students' lived experiences of simulating at the frontier of the ZPD into a quotation-rich composite textural description (see Supplemental Digital Appendix 3 at http://links.lww.com/ACADMED/A811). In this section, we have provided a composite structural description, which is our interpreted synthesis of the meanings of the students' experiences of the phenomenon.

We have also distilled these experiences into their essence, also included in this section. We found 3 distinct core themes to be relevant to the research question: realism, emotional response, and motivation to learn.

Realism

Students generally experienced the simulation area, manikin, and scenarios as realistic. Participants were highly appreciative of the authenticity of the simulation, and some were impressed by it: "I was astounded, finding myself giving orders or instructions to a nurse and pressing the defibrillator button. I couldn't stop thinking about this experience the rest of the day" (Participant [P]2).

All students believed they could encounter similar situations as newly qualified doctors. They perceived the manikin almost as a person, eliciting in some a desire to "rescue the patient" and "comfort him." Despite the high level of realism, all students were continuously aware of being in a simulation: "I was kind of assuming the manikin was going to crash. So I was thinking about the diagnosis: What could it be? And what could then go wrong?" (P11).

Emotional response

The main emotion students experienced during the simulation was universally described as stress. Many students also experienced a sense of responsibility and a feeling of failure.

Stress. The amount of stress varied from person to person. In most cases, feelings of stress were related to the uncertainty about diagnosis or treatment options. Although some noticed palpitations and sweating, most students were not aware of a physical stress response but did experience stress mentally. Students described feelings of being frozen in place or time:

> The pulse oximeter made a penetrating, beeping sound. It felt like time stood still…. If you don't know what to do, then every second is painful and feels like a minute. (P3)

Many felt overwhelmed, had difficulty structuring their thoughts, struggled to prioritize, or forgot what they intended to do:

> When I saw on the monitor that it wasn't going well, thoughts were racing through my mind. "It could be this, or this, or this." (P6)

> But then I realized I'm reading the sheet with CPR instructions, but I'm not processing them. (P8)

A significant contributor to stress was students' perception of their performance:

> I don't stress out easily, but on the other hand, I do have certain expectations of myself. So it is stressful in a sense of not being able to live up to those expectations. (P7)

The level of stress increased when the patient deteriorated: "I was sweating more, had a real adrenaline rush. It made me double my efforts, but once the patient deteriorated, I started to feel a little claustrophobic in that room" (P2).

The constant awareness of being in a simulated environment eased feelings of stress. The atmosphere at the simulation center helped to reduce tension:

> I was pleasantly surprised to find out that I stayed calm and was still able to think…. I knew it was a manikin, and a disastrous situation was going to be created. I did realize something is going to happen that won't necessarily be my fault; I just need to solve it to my best ability. (P10)

Students emphasized that although the experience was stressful, they still enjoyed the simulation. It felt gratifying to solve a puzzle, experience a unique learning opportunity, and realize they were able to handle complex medical situations to a certain degree:

> Besides knowing where I should be at the end of medical school, it gives me a sort of confidence, knowing I am capable of helping out in an emergency situation until the real team arrives. (P9)

Sense of responsibility and failure. The students' perception of role was fluid during the scenarios. Most students initially felt like junior doctors, finding it exciting and novel to give directions to the nurse: "I felt like a real doctor in the simulation. This was one of the few times I felt completely responsible for a patient. I realized this immediately. And it felt quite good" (P2).

Often, this initial feeling of confidence faded upon encountering urgent situations in which the course of action was not evident. Students experienced a significant degree of incompetence, and their self-image changed from junior doctor to medical student. Also, they felt they were being unprofessional when giving unclear instructions or retracting orders:

> I felt like crawling into a corner…. I was like, "Oh dear, I am sending her all over the shop!" (P6)

> There were brief moments when I knew what to do. Those felt like being a resident doctor. But as soon as I thought "help!" I was more like, "I'm a medical student. I don't know!" (P8)

Often, the student's uncertainty reverted to confidence when the patient had a cardiac arrest. Having a protocolled basic life support algorithm to execute provided the students a paradoxical sense of relief during this specific clinical deterioration. (However, none of the students mastered the advanced life support algorithm satisfactorily.) "If the patient arrests, it places you on firm ground. At least you can do something" (P3).

Self-assessment of performance varied from "outright failure" to a "bare pass." Most students expected not to perform well and did not mind because the pretest was formative. The students' perceptions were in accordance with the test results: Most students scored low on all 3 scenarios. "I can't really say I felt angry or like a very big failure because I didn't expect to perform much better than I did" (P6).

Despite the expectation of failure and the formative nature of the pretest, all students regarded their performance level as "a shocking revelation" and "disappointing."

> It was so bizarre that I didn't notice the patient was basically bleeding out. It was so obvious!… It's just a shocking revelation. Because at that moment, I realized I am far from knowing enough [to manage] such a situation. (P6)

> It was very intense. I was confronted with my incompetence, and the realness of the simulation, and the demanding nature of emergency situations. It truly was a mirror. (P3)

Students were aware of faculty witnessing their performance through the one-way mirror but generally did not mind that staff were assessing their performance. During moments of uncertainty, students became slightly more aware of the one-way mirror: "I am being watched. I must do something!" (P3).

In addition, most students felt relieved at the end of the scenario, especially if they were uncertain about the management of the case: "If it went that badly, then [the end of the scenario] felt like a kind of relief. Like being put out of my misery" (P4).

The informal and nonjudgmental atmosphere in the simulation center contributed significantly to the students' not minding being watched and scored. All students appreciated that staff introduced themselves at the start of the day, so they knew who was observing them: "It was really helpful that the staff acted very casual at the start of each simulation and often made a joke. For me, that reduced the tension" (P2).

Motivation to learn

All students found the short personal debriefing sessions after each scenario crucial to their learning. They appreciated the immediate and to-the-point nature of these sessions and that staff highlighted not only mistakes but also correct actions. In addition, students found that being able to vent emotions in a safe and nonjudgmental environment was a valuable experience: "You only learn from mistakes if you get the correct answer later or if you can discuss it. Without that debriefing, the simulation would be far less useful" (P4).

In most cases, the simulations reinforced the students' orientation toward acute medicine. None felt that the simulation had demonstrated they were unsuitable to work in acute medical specialties. But their experiences in the simulation did make them more aware of the challenges ahead and motivated them to improve themselves.

> Without the simulations, I also would have started my final-year clerkships. But perhaps I would have been more passive. Now I really want to get the most out of this year. (P2)

> It [the simulation] reinforced my aspirations. This is what I want to excel in so I'd better put in some effort now because I want to do better than I did today. (P3)

In the days following the simulation, all students reflected on their experiences positively. The simulation pretest made the students more aware of the goals and requirements of the program, and the students expected that their experience with the simulation would direct their learning in the year ahead.

> From now on, when situations like these occur, I'll perceive them differently. I'll try to engage more with what's happening at the time. (P11)

> It is very informative to know what's expected of me once I qualify…. It [the level expected of a qualified junior doctor] is a sort of guideline, outlining the gaps in my knowledge. It demonstrates what I should study in greater depth or what I should pay attention to during my clerkships. (P9)

Essence

Students experienced difficulties in managing simulated acute care situations, leading to a significant amount of stress fueled by uncertainty about medical management, deterioration of critically ill simulated patients, and disappointment about their performance. Their stress manifested itself mainly mentally, impeding cognitive function. Students reported that awareness of the practice setting, anticipation of poor performance, debriefing, a safe learning environment, and the prospect of training opportunities regulated their emotional responses to stress. These stress-regulating factors turned stressful simulation into a motivating educational experience.

Discussion

Our study explored the psychosocial and educational impact of simulation at the frontier of the ZPD in medical students after a residency-level pretest of acute care competence at the start of the students' final year.

Our main finding is that, in a formative preassessment setting, simulation at the far edge of the ZPD causes constructive friction leading to an experience that generates a motivation to learn. This finding contrasts with the current opinion that the difficulty of the simulation task should be tailored closely to the developmental level of the participant[10] to avoid destructive friction and demoralization.

The ZPD spans the difference between an individual's current level of capabilities and the level of functioning needed in the next stage of development.[2] The ZPD comprises maturing functions relevant for the next level of capability, activities that cannot be carried out independently but that can be taught or carried out with direction, generally from a teacher.[2] We exposed students to activities from their next stage of development, that of a junior physician, without providing teacher support or direction. The students' inability to sufficiently manage the activities indicates that these activities were at the far edge of their ZPD. In addition, students perceived shifts between doctor and student identities; this shift can be seen as an indication that the simulations were at the ZPD's frontier, with participants moving back and forth over the border between their current level and the next developmental level.

Study participants indicated that their stress was caused by their uncertainty about medical management, the deterioration of the simulation patient, and disappointment about their performance. The discomfort of an undesirable outcome in dramatic cases in which "things go wrong" has recently been identified as a key feature of powerful simulation experiences.[19] Without appropriate facilitation, this disruption could be damaging, but debriefing and feedback may turn the simulation into a powerful learning experience.[19] In other words, a challenging task can induce the development of new skills if the teacher provides tailored direction, creating constructive friction. Without direction, destructive friction may occur, decreasing learning.[3]

The students' stress manifested in feelings of bewilderment and disturbance of cognitive processes. The detrimental effect of stress on cognitive function during simulation is due to a reduction in "tranquility," leading to agitation, combined with positive feelings of "invigoration."[13] These reactions are associated with an increase in task-irrelevant, extraneous cognitive load and thus reduce working memory space for learning.[13,32] Extraneous load caused by invigoration may include self-evaluating thoughts on performance,[13] and indeed some participants feel exposed during simulation.[33] Students in our study worried about their performance and the impression they made on faculty, especially when they felt they were performing poorly. Disappointment made them aware of being observed and assessed.

In our study, students engaged in the management of critically ill simulation patients who deteriorated despite the students' best efforts, with some cases ending during cardiac arrest, as case duration was limited due to time constraints. Whether patient death in a simulation affects cognitive load, stress, or learning outcomes remains controversial.[11,14,34–36]

Cases that are beyond the learner's control may lead to the learner's disengagement and impair his or her ability to handle the situation.[37] Of interest, participants in our study experienced a sense of control that brought them relief in the case of cardiac arrest. So, although the patient was moribund, the situation provided solid ground for protocolled action (i.e., students suddenly knew what to do); we suggest calling such a situation "the paradox of cardiac arrest" in simulation. This finding also indicates the importance of teaching students how to prevent cardiac arrest by recognizing and treating deteriorating patients, which we chose as an objective of our transitional year.[26]

The students' emotional response to the stressful simulation was regulated by awareness of the practice setting. Previous research has suggested that when participants expect a life-threatening event or negative outcome to occur, their level of stress is reduced during a simulation.[38]

Students' anticipation of poor performance was another stress modifier. The pretest worked as an eye-opener that explicated the level of performance that would be required for graduation. It motivated the students to exploit learning opportunities during the year: Preassessment can drive learning. The beneficial effect of a pretest on subsequent learning has recently been demonstrated in surgical skill acquisition.[39] The educational effect of the pretest is rooted in the close alignment between simulated cases and the learning objectives tested,[10,40–42] in this case the EPAs of a final year focused on acute care.[26] Because of the pretest, students started their final year with a clear view of the learning objectives.[27] Their choice for this specific final-year elective program and their interest in acute care moderated their response to the pretest.

Finally, the developmental atmosphere in the simulation center created a safe learning environment and helped make the test a motivating experience. In general, positive emotions can improve cognitive processing and increase motivation.[43] Previous research highlighted that learning and using stress-coping strategies in simulation training and assessment helped students turn negative emotions into positive ones.[14–16] In addition, feedback in the form of debriefing is crucial for the educational effectiveness of simulation[10,40,42] because it improves the transfer of learning after simulation.[44] Debriefing helps to restore tranquility, thereby reducing extraneous cognitive load and providing space for learning.[43] Venting emotions is a good starting point for a debriefing session to increase the students' tranquility before they focus on medical and crew resource management aspects of their performance.

In the simulations, students took on the role of doctor, but this self-image crumbled when they experienced feelings of incompetence. The resultant disappointment subverts students' common belief that doctors should be in control even in complex situations, which influences emotional and behavioral responses to challenging clinical situations.[37]

The response to complex situations could be a topic for the debriefing to help students be reflective about their expectations of being in control.

Implications

We found that simulations of challenging stressful acute care situations, without guidance during scenarios and despite poor participant performance and simulation patient outcome, do not demoralize participants but rather lead to positive, instructive, and motivating experiences, when conducted in safe, formative, developmental circumstances.

Our findings imply that simulations at the far edge of the ZPD may be used safely to motivate learners. This finding contrasts with current opinion on simulation learning[10] and has practical significance by providing preliminary data on simulating beyond traditional borders.

Limitations

Our study had several limitations. We conducted an explorative study in the specific context of pretested students at the start of a final year focused on acute care. The study did not control for the extent to which the far edge of the students' ZPD was reached, nor did it include control groups of participants with variable levels of competence or intrinsic motivation. Also, the study reached theoretical sufficiency, that is, there was no need for additional constituent or core themes to categorize new data, with a relatively small number of interviews, which could be attributable to participants all being part of the same elective track. Lived experiences could have been more divergent in a random sample of students. Future studies could investigate the phenomenon in other groups, including students with less focus on acute care and graduating students. Another limitation is that we did not measure a longer-term learning effect. Participants stated that the simulation was a valuable learning experience, but we did not test for educational effectiveness. By providing a precise description of the context, we aimed to improve the transferability of our data and provide generalizable insights regarding the ZPD in the context of simulation. Better comprehension of the psychosocial and educational impact of exposing inexperienced learners to activities far outside of their comfort zones may support the responsible and effective use of simulation at the ZPD's frontier, such as in preassessment. Further research could investigate the effects of teacher support and instructional design on students' experiences of crossing the ZPD border in simulation.[2,6]

Conclusion

This study demonstrated that simulation at the frontier of the ZPD evokes a significant amount of stress, impeding cognitive functioning but also causing constructive friction that leads to a motivating experience in untrained learners. Our premises for this type of simulation are that a safe and formative learning environment is offered, the practice setting is emphasized, feedback and debriefing are provided, and the prospect of further training is present. In this way, experiencing failure turns into a successful learning experience.

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