Assessing Medical Students' Nontechnical Skills Using Immersive Simulation: What Are the Essential Components?

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Introduction: Nontechnical skills (NTS) have been acknowledged to be important for medical students and can be linked to improved clinical performance. However, existing tools to evaluate these within a simulated setting address only a limited number of NTS. The Medical Students' Nontechnical Skills (Medi-StuNTS) behavioral marker system (BMS) outlines 5 categories of NTS for medical students. This study aimed to seek evidence for completeness and content validity to refine the BMS and to ascertain which NTS are essential for medical students.
Methods: We asked 128 workshop participants if they felt there were any missing or irrelevant items in Medi-StuNTS system. A subject matter expert panel (n = 10) rated how essential they considered each item in the BMS. An Item-Content Validity Index was calculated for each skill element and the Scale-Content Validity Index was calculated as a measure of content validity of the full system.
Results: Of the workshop participants, 78.9% felt that there were no missing items and 93% felt that there were no irrelevant items. Potentially missing items highlighted were as follows: "working in a hierarchy," "leadership," "awareness of the emotional state of other team members," and "nonverbal communication." Fourteen of 16 skill elements achieved the recommended level for content validity (Item-Content Validity Index $\geq$ 0.78), and the Scale-Content Validity Index was higher than the acceptable level ($\geq$0.8).
Conclusions: Evidence for completeness and content validity of Medi-StuNTS has been demonstrated. There is a far wider range of NTS that seem to be essential for medical students than those assessed by tools developed before Medi-StuNTS. Medi-StuNTS provides comprehensive cover of the essential NTS required by medical students, with specific reference to the skill categories "self-awareness" and "escalating care," which do not feature in other tools for assessing NTS in this group.
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The Medical Students' Nontechnical Skills (Medi-StuNTS) behavioral marker system (BMS) was recently developed as the first BMS specifically for nontechnical skills (NTS) of medical students.[1] Developing and implementing NTS have been shown to improve patient safety,[2,3] and training in NTS is being adopted by a wide range of clinical specialities.[4,5] With medical students, it has been shown that better NTS correlates with clinical performance in the context of a simulation scenario[6] and that these skills are teachable.[7]

The purpose of Medi-StuNTS is to facilitate training and assessment of NTS during immersive simulation scenarios. Behavioral marker systems are often used for this purpose, with one of their key features being that they clearly outline categories of NTS and give examples of behavioral anchors that may be observed during a simulation scenario.[8] Medi-StuNTS follows this structure by outlining 5 skill categories: "situation awareness", "decision making and prioritization", "teamwork and communication," "self-awareness," and "escalating care." Figure 1 illustrates the structure using the example of the skill category "situation awareness." Although there are a number of existing BMS, Medi-StuNTS is the first to be developed specifically for medical students. It has been iteratively developed, and through that process, a brand new category that seems to be particularly pertinent to medical students emerged from the data—self-awareness.[1] This category has not been described in any of the other published BMS. The development process of Medi-StuNTS would suggest that although there is clearly overlap, different groups of learners require different NTS to be emphasized to direct their learning in the most appropriate way for their level of responsibility and scope of practice.

A recent Best Evidence Medical Education review[9] highlighted marked heterogeneity in the NTS included in assessment tools for medical students. This review also demonstrated that simulation-based assessment tools address a limited number of NTS, namely, situation awareness, managing distraction and interruption, and teamwork. Higham et al's[10] systematic review of NTS assessment tools similarly

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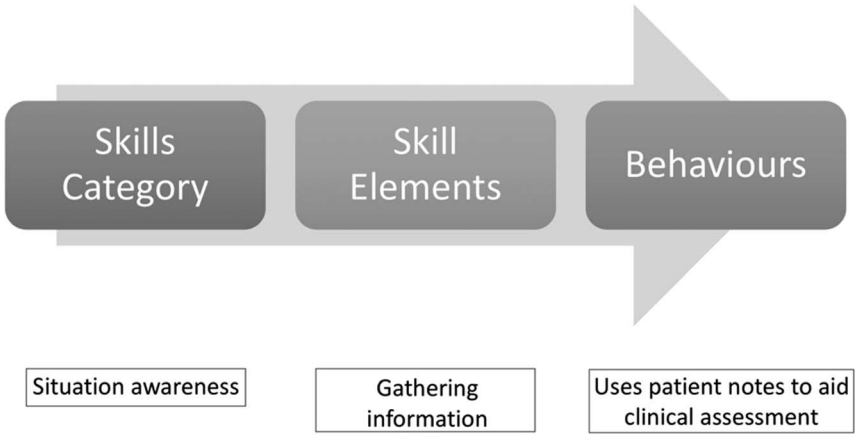

FIGURE 1. Structure of the Medi-StuNTS system: example given for "situation awareness" skill category.

demonstrated that tools for medical students tended to be focused on teamwork, communication, and assessment of the situation. Key differences between Medi-StuNTS and other BMS are not only the type of NTS described but also the broader range of NTS in Medi-StuNTS. Developing a range of NTS is superior to mastery of individual skills,[2] and therefore, having an assessment tool that reflects this is crucial.

Establishing the validity of a tool is a critical step toward ensuring its utility.[11] Messick's contemporary framework outlines 5 forms of validity: content, response process, internal structure, relations with other variables, and consequences.[12,13] Content validity is defined as "the extent to which items of a measurement instrument are important and relevant to a performance context"[14] and is acknowledged to be a fundamental element of all educational instruments.[15] Methods of assessing content validity for BMS include literature reviews, expert panels, formal task analysis, and adaptation of existing frameworks.[16] A recent systematic review[10] of 76 tools for the measurement of NTS found that although general validity evidence for these tools was variable, all tools had assessed content validity in some form. In a review of validity evidence for assessment tools for simulation, Cook et al[16] found that issues with other measures such as reliability and response process could sometimes be traced back to low-quality content validity.

For these reasons, the authors recognized that content validity evidence for Medi-StuNTS would be required before establishing its use in medical student simulation-based education. The preliminary work in developing Medi-StuNTS included initial aspects of content validity assurance,[1] including a literature review, initial expert panel review to develop the prototype BMS, and review by a second expert panel to further refine it. However, it had not yet undergone content validity assessment in its resultant form or using a formalized validity scale. One further aspect of content validity is completeness, "the scope to which the measurement is comprehensive and captures all behaviors,"[5] which has been assessed for a small number of other BMS.[4,5]

The aims of this study were (1) to assess the completeness of the Medi-StuNTS BMS and (2) to assess the content validity of the Medi-StuNTS BMS.

These assessments have provided insight into which NTS are deemed essential for medical students and can be used to further refine and improve the BMS.

METHODS

This study received ethical approval from the University of Edinburgh College of Medicine and Veterinary Medicine Student Ethics Committee (Approval Number 2017/11). All participants gave written informed consent and were free to leave the study at any time without giving a reason.

Stage 1: Completeness

Study Design

Completeness of the BMS was assessed via questionnaires distributed after workshops on the use of Medi-StuNTS in simulation-based education.

Context and Participants

Eight workshops were held for a 20-month period across 5 sites: The University of Aberdeen (August 2017; Aberdeen), Scottish Medical Education Conference (April 2018; Edinburgh), The Scottish Clinical Skills Network Meeting (June 2018; Glasgow), The Association for Simulated Practice in Healthcare Annual Meeting (November 2018, Southport), and The Scottish Centre for Simulation and Clinical Human Factors (February 2019, March 2019, March 2019, and April 2019; Larbert). Workshops were advertised as being suitable for anyone involved in the training of medical students, particularly in relation to immersive simulation. At the beginning of the workshops, Medi-StuNTS and its use were described. Videos of medical students in simulated acute care scenarios were shown to allow workshop participants to practice using the BMS. Facilitated discussion between workshop participants and faculty (E.C.P., V.R.T., J.K., B.C., A.L.H.) took place after the video marking. The workshops each lasted between 90 minutes and 3 hours. The length of time of the workshops was determined by the conference programming.

Participants attended the workshops on a voluntary basis. All participants were professionals involved in the delivery of simulation-based education and came from a range of clinical backgrounds. None were directly involved in the development of Medi-StuNTS.

Data Collection

At the end of each workshop, participants were asked to complete a feedback questionnaire. The questionnaire related to aspects of the Medi-StuNTS system itself, as opposed to feedback on the workshop. Completeness was assessed by

asking participants whether they thought there were any missing or irrelevant items in the Medi-StuNTS and gave space for free-text comments. The questionnaire also asked participants if they felt Medi-StuNTS addressed key NTS behaviors displayed in the videos they had watched.

Data Analysis

Data were analyzed by basic frequency analysis. There is no widely accepted standard for completeness; however, other BMS have been found to have more than 80% responses agreeing that there are no missing or irrelevant items.[4,5]

Content review of free-text comments was performed[17] (by E.C.P., S.E.S., and V.R.T.) for the questions regarding any missing or irrelevant elements. This was done to identify themes de novo and was not based on a preexisting framework. The missing elements identified were then taken to the subject matter expert (SME) panel for comment, as described in stage 2 hereinafter.

Stage 2: Content Validity

Study Design

We invited SMEs in simulation and NTS to participate in a further review of Medi-StuNTS.

Context and Participants

For the purpose of this study, SMEs were defined as individuals with 5 or more years of experience in delivery of simulation-based education. Participating SMEs were selected via purposive sampling[18] (by E.C.P. and V.R.T.). We identified SMEs from a range of different clinical backgrounds and geographical locations. Those involved in the expert panel review during the BMS development process were excluded. Fifteen SMEs were invited by e-mail. The e-mail included a cover letter stating the purpose of the research and the rationale for their invitation to the SME panel. It also included background information on the development of Medi-StuNTS to explain its conceptual underpinnings.[15] After agreeing to participate, SMEs were sent the rating form shown in Supplemental Digital Content 1, http://links.lww.com/SIH/A680. Between 5 and 10 judges is thought to be an acceptable number for assessment of content validity[14]; therefore, data collection was discontinued once 10 SMEs had returned their rating forms.

Data Collection

The rating form is shown in Appendix 1. We asked SMEs to assign a label of "essential," "useful but not essential," or "not essential or useful" when considering the NTS of a medical student related to each skill element of Medi-StuNTS. Subject matter experts were also asked to assign labels to the potentially missing elements highlighted from the review of free-text comments from workshop participants. Rating forms were returned via e-mail and stored on a secure computer.

Data Analysis

Data from the rating sheets were collated and analyzed using Microsoft Excel. The Item-Content Validity Index[19] (I-CVI; Table 1) was calculated for each skill element, with good content validity for an individual item indicated by an I-CVI of 0.78 or greater.[14] The Scale-Content Validity Index[19] (S-CVI; Table 1) was calculated as a measure of content validity of the full system, with a S-CVI of 0.8 or greater generally deemed an acceptable minimum,[20] and 0.9 or greater being the ideal standard.[21] The I-CVIs were also calculated for each of the potentially missing items. Formal thematic analysis of the SME free-text responses regarding the potentially missing items was not undertaken because of the small number of comments.

TABLE 1. Calculations for the I-CVI and S-CVI

I-CVI = number of panelists rating each item as "essential" / number of panelists
S-CVI = mean of the I-CVI values for all items in the system

RESULTS

Completeness

A total of 131 participants attended the workshops, and 128 of these completed the questionnaire (97.7% response rate). Of the workshop participants who provided demographic data, the median age was 30 years (range = 25–-69 years). Regarding their level of clinical experience, 42% had between 2 and 5 years of clinical experience, 31% had between 5 and 10 years of clinical experience, and 27% had more than 10 years of clinical experience. They were from a range of clinical backgrounds including anesthetics, medicine, surgery, emergency medicine, nursing, orthopedics, general practice, radiology, and pediatrics. Seventy-nine percent felt that there were no missing categories or elements, whereas 93% felt that there were no irrelevant categories or elements. One hundred twenty-five participants (97.7%) agreed or strongly agreed that the system addressed the key NTS behaviors displayed by the medical students in the videos they had watched.

There were 30 free-text comments regarding potentially missing items that then underwent content review. Seven comments (23.3%) stated that they were happy with the system as it was, 5 (16.7%) were not related to completeness, and 18 comments (60%) gave suggestions for changes. Of the comments suggesting a change, 7 suggested additions that were already present. New items suggested were as follows: "working in a hierarchy" (cited once), "leadership" (cited 5 times), "awareness of the emotional state of other team members" (cited twice), "nonverbal communication" (cited once), and "patient safety" (cited twice). "Patient safety" is known to be an important consequence of high-quality NTS; however, it is not a skill in itself.[3] Therefore, only the former 4 items in this list were presented to the SME panel.

There were 17 free-text comments relating to irrelevant items. One respondent stated that they felt "escalating care" was an irrelevant category. All other comments related to either the layout or the degree of overlap between skill elements rather than to irrelevant categories themselves.

Content Validity

Ten SME questionnaires were analyzed. The SMEs had a mean of 10.5 years of experience in simulation-based education (range = 5–22 years). They were from 7 hospitals across 5 health boards in Scotland and were from a range of clinical backgrounds as shown in Table 2. All the SMEs reported regularly teaching medical students and debriefing on NTS.

The I-CVIs for the skill elements of Medi-StuNTS ranged from 0.6 to 1, as shown in Table 3. Fourteen (87.5%) of the 16 skill elements achieved an I-CVI of 0.78 or greater. The S-CVI for the full Medi-StuNTS system was 0.88. If the 2 skill

TABLE 2. Subject Matter Expert Demographics

SME	Experience in Simulation-Based Education, y	Clinical Background	Region of Work
1	5	Obstetrics and gynecology	NHS Forth Valley (West of Scotland)
2	5	Acute medicine	NHS Lothian (Southeast Scotland)
3	5	Nursing	NHS Forth Valley (West of Scotland)
4	7	General practice	NHS Tayside (East of Scotland)
5	7	Surgery	NHS Lothian (Southeast Scotland)
6	10	Anesthetics	NHS Lothian (Southeast Scotland)
7	14	Nursing	NHS Lanarkshire (West of Scotland)
8	15	Emergency medicine	NHS Ayrshire and Arran (West of Scotland)
9	15	Nursing	NHS Tayside (East of Scotland)
10	22	Anesthetics	NHS Lothian (Southeast Scotland)

elements that did not achieve an I-CVI of 0.78 or greater (planning, preparing, and anticipating; coping with stress) are excluded, the S-CVI is 0.91.

The items that had been highlighted as missing by the workshop participants had I-CVIs ranging from 0.2 to 0.4, with less than half of SMEs feeling that any of these items were essential. Free-text comments regarding these items are shown in Table 4.

DISCUSSION

The objectives of this study were to seek evidence for Medi-StuNTS in the form of completeness and content validity through a 2-stage process. Most workshop participants (78.9%) felt that there were no missing items, and 93% felt that there were no irrelevant items. Four potentially missing items were highlighted. Fourteen of 16 scale items achieved an acceptable content validity index from the SME review.

Previous studies assessing completeness of a BMS have found between 84% and 88% of participants stating that no items were missing.[4,5] There are key differences between our study and those published previously, which assessed the completeness of Anaesthetists' non-technical skills (ANTS)[4] and the Scrub Practitioners' List of Intraoperative Nontechnical Skills[5] (SPLINTS). Firstly, we used a larger number of participants, and secondly, the participants in these studies were homogeneous groups (ANTS used 50 consultant anesthetists; SPLINTS used 34 scrub practitioners). The background of faculty involved in medical student education is much more disparate, and we felt that it was important to include participants with a wide variety of clinical backgrounds to reflect this. There is no widely accepted standard for completeness, and we were satisfied that although lower than the figures shown in the ANTS and SPLINTS studies, 78.9% was an acceptable level of completeness for Medi-StuNTS.

One workshop participant stated that they felt the "escalating care" category was irrelevant. This category was incorporated into Medi-StuNTS during development as it was noted as a recurring theme from both medical student interviews and the expert panel review.[1] Escalating care appropriately is critical to preventing avoidable harm and reducing patient mortality[22,23]; medical students and newly qualified doctors will not yet have the required skills to independently manage many acutely unwell patients. We found it compelling that the I-CVI for skill elements within this category were 0.8 to 0.9, indicating good content validity. We maintain that this category should remain a part of Medi-StuNTS.

The overall S-CVI for the Medi-StuNTS system was 0.88, which is well above the acceptable level of 0.8 for the scale and just slightly below the ideal level of 0.9. Based on the results of the SME review, Medi-StuNTS in its entirety has been shown to have good content validity.

Only 2 items did not achieve the recommended standard of I-CVI by the expert panel, and these were planning, preparing, and anticipating, and coping with stress. This may be because both of these are viewed as more advanced NTS that develop with clinical expertise[2] and therefore are not as critical at the medical student level. "Planning, preparing, and anticipating" is the advanced level of situation awareness.[24] Performance in this improves with clinical experience and exposure to clinical situations, which help develop pattern recognition and primed decision making.[25,26] The ability to adequately cope with the acute stress of managing an unwell patient is important for individual and team well-being and has been linked to patient safety outcomes.[2] Moreover, because acute stress can impair concentration and decision making ability, effectively coping with stress may also improve performance in other NTS categories. Although some individuals cope better than others, responses to stress can be learned.[27,28] Medical students are fully supervised during their clinical practice; thus, they may have not yet experienced the pressures associated with patient care.

Although the skills of planning, preparing, anticipating, and coping with stress seem to be important, they were not deemed essential NTS for medical students by the SME review. This is perhaps because they may be considered to be skills that are not required until the stage of being a qualified doctor. However, this could be challenged. As noted by Flin and

TABLE 3. The I-CVI for Skill Elements in the Medi-StuNTS System

Skill Category	Skill Element	I-CVI
Situation awareness	Gathering information	1
	Recognizing and understanding information	0.9
	Planning, preparing, and anticipating	0.7
Decision making and prioritization	Prioritizing	0.9
	Recognizing and dealing with uncertainty	0.9
	Reviewing decisions	1
Teamwork and communication	Establishing a shared mental model	1
	Demonstrating active followership	0.9
	Patient involvement	0.8
Self-awareness	Role awareness	0.9
	Coping with stress	0.6
	Speaking up	1
Escalating care	Situation awareness for escalating care	0.9
	Decision making and prioritization for escalating care	0.8
	Teamwork and communication for escalating care	0.9
	Self-awareness for escalating care	0.9

TABLE 4. The I-CVI and Free-Text Comments From SMEs on Items Potentially Missing From the Medi-StuNTS System

Suggested Skill Element	I-CVI	SME Comment
Working in a hierarchy	0.2	SME 4—"To my mind all teamwork involves working within some form of hierarchy. I am uncertain what this would add when "role awareness," "speaking up," and "teamwork" already exist." SME 5—"Students are well aware of hierarchy in the workplace—I do not think this needs reinforced." SME 10—"For me, it's already covered in 'demonstrating active followership'."
Leadership	0.4	SME 1—"I have spent a lot of time talking about leadership, followership and 'fluid leadership'—role awareness covers this better." SME 4—"You have chosen active followership above. I do not think you can have both in one tool very easily." SME 5—"I completely agree that predominant role in acute situations will be followership but do want to encourage willingness to lead, particularly in early phases of resuscitation where FY1/2 commonly first on scene." SME 10—"Covering aspects of leadership will help students to appreciate followership and working in a hierarchy. I do not think we should be focusing on performance of leadership at undergraduate level, but an introduction to it would be useful."
Awareness of the emotional state of other team members	0.2	SME 2—"Less around them dealing with it personally but more feeling comfortable to escalate any concerns regarding the emotional state of other team members to their seniors." SME 5—"Given the predominant focus on followership I do not think it needs included. Additionally, the self-awareness section will promote reflection/understanding of emotion/stress in others as well as self."
Nonverbal communication	0.4	SME 1—"Generally covered by observation of teamwork and communication." SME 2—"It would be helpful to be aware of nonverbal signals that might be given by other members of the team during a stressful situation as part of communication." SME 4—"Although this is an important aspect of communication, I would see no reason to separate it out and would see it as an implicit part of any discussion around communication." SME 5—"I think this would be very difficult if not impossible to observe objectively in a BMS." SME 7—"I think this would be covered as part of teamwork and communication."

Patey,[29] to fully develop and value NTS, training should take place at student level, while professional skills and attitudes are being formed. It is therefore difficult to differentiate whether these skills are not deemed critical for medical students because we do not tend to focus on them or whether we do not tend to focus on them because they are not deemed as critical. The opinions of the expert panel on Medi-StuNTS are highly regarded because of the wealth of expertise within this group. However, it may be that these skills are globally underrepresented for medical students. Of course, it is not practical to teach every single skill to students, and any attempt to do so risks them becoming overwhelmed and disengaged. Perhaps changing the focus to introductory level teaching of these more advanced NTS is preferable. On the basis of the SME review and the available literature, we suggest de-emphasizing these skill categories within Medi-StuNTS to make them "useful" but not "essential," as opposed to removing them entirely.

The SMEs took into consideration the potentially missing items highlighted by the workshop participants, and more than half the SMEs did not feel that any of the potentially missing items were essential for medical students. For the items of "working in a hierarchy," "awareness of the emotional state of other team members," and "nonverbal communication," the free-text comments mostly reflected the opinion that these skills would be covered by other elements of Medi-StuNTS or that they would be difficult to observe using a BMS. These items were therefore disregarded as potential additions to the tool. "Leadership" was the most frequently cited potentially missing item from the workshop participants, and although the SME review yielded a low content validity index, free-text comments on this item were thought provoking. These comments hinted at the possible tension of having both leadership and followership in the same tool. The comments also suggested that although leadership is a skill that medical students should have some training in, it is not one that they need to master. Of note, leadership was included in the prototype Medi-StuNTS BMS but was not included in the final BMS because of the expert panel agreeing that "in the simulated acute care environment, medical students are all of the same level of clinical experience and this skill is therefore less relevant than in other BMS."[1] Instead, Medi-StuNTS focuses on followership, being "proactive support of the leader and participation in team activities."[1] Followership and leadership are intertwined and skills in both will impact the level of communication, coordination, and likely successful outcomes achieved by a team.[30] There are existing tools that focus on the assessment of medical students' teamwork during simulation,[31–34] each focusing on various elements of teamwork including leadership. Although these tools address different facets of leadership including performance standard and style, there is little evidence to indicate how important the contribution of leadership is to good overall team performance of medical students during simulation. This may be because of the lack of a natural hierarchy during simulation scenarios, which makes it challenging to observe specific leadership behaviors. What is certainly agreed is that teamwork as a whole is a critical concept for delivering good patient care and that simulation-based education is an effective methodology for team training.[35] Therefore, we must find a suitable way for Medi-StuNTS to optimize delivery of skills related to working in a team. We propose developing an alternative version of Medi-StuNTS to reflect the leadership role by amending the original "followership" version to a "leadership" version for use when a particular student is acting as the leader in a scenario.

Strengths and Limitations

We assessed completeness using a large number of workshop participants, therefore reflecting a wide range of opinion and expertise. In addition, all workshop participants received a minimum of 90 minutes of training on using Medi-StuNTS and had the opportunity to utilize it before completing the questionnaire. The workshop lengths varied from 90 minutes to 3 hours, and this may have influenced the familiarity with using the BMS. In theory, this may present a limitation to the

interpretation of the results; however, we feel that enough time was provided in each workshop for participants to be able to comment on the content of Medi-StuNTS. Content review of the qualitative responses from the workshop participant questionnaires did not use a preexisting framework, and this may present a limitation to the quality of this analysis.

Expert panels are one of the most frequently used methods for content validity assessment[16] but do have their limitations. Our SME group was small (n = 10) and was selected by purposive sampling by the researchers, which has potential for the introduction of bias. However, selection of this group was made carefully with particular consideration relating to diversity of both clinical and geographical backgrounds. These standards are critical in the selection of an expert panel but are historically infrequently reported.[36] This study used questionnaires, and it must be acknowledged that these can only be reflective of the opinions of those completing them at that point in time. Further risk of bias exists as the SME questionnaires were not anonymous. The focus of this study was on NTS relevant for medical students specifically during immersive simulation, and these do not necessarily reflect what is important for real clinical practice.

Further Research

Future work should look at making adjustments to Medi-StuNTS to reflect the expert review. This should include de-emphasis of the skill elements "planning, preparing, and anticipating" and "coping with stress," and developing an alternative "leadership" version of the BMS. This study has focused on validity primarily from the educator perspective. Future research should address the student perspective by looking at educational impact and face validity, which would fall under the "consequences of testing" element of the validity framework.[13] It should also aim to seek other forms of validity, reliability, and practicability evidence to ensure that Medi-StuNTS is robust.[11]

CONCLUSIONS

We have provided evidence for completeness and content validity of the Medi-StuNTS system, which is a critical step in ensuring it is a fit-for-purpose tool for the assessment of NTS of medical students during immersive simulation. This evidence has highlighted that there is a far wider range of NTS that are essential for medical students in the context of simulation than those assessed by tools developed before Medi-StuNTS[9,10] and suggests that some skills that are frequently emphasized are not actually critical until further on in clinical training. Medi-StuNTS provides comprehensive cover of the essential NTS required by medical students, with specific reference to the skill categories "self-awareness" and "escalating care," which do not feature in other tools for assessing NTS in this group.

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