REVIEW ARTICLE

Paediatric simulation teaching for medical students: a review of current literature

Co-First Authors

Ashani Mahawattege
Bachelor of Medicine and Bachelor of Surgery
Six-year degree, currently in sixth year.
University of Adelaide
Student
Email address: ashani.m@hotmail.com

Samantha Burns
Bachelor of Medicine and Bachelor of Surgery
Six-year degree, currently in sixth year
University of Adelaide
Student
Email address: s_c_burns@hotmail.com

The authors are sixth year undergraduate medical students studying at the University of Adelaide, who share a special interest in paediatrics and child health. This review was inspired by a Simulation Education Selective undertaken together at the Adelaide Health Simulation and Skills Centre.

Source of submission
Prepared specifically for AMSJ.

Summary
This article reviews current literature to answer the question: could simulation teaching enhance the teaching of paediatrics to Australian medical students?

Keywords
paediatrics, simulation, education, medical student

Number of tables: 0

Number of figures: 1

Word count: 2948 words

Abstract

The objective of this review article is to determine whether simulation-based education could enhance the teaching of paediatrics to Australian medical students.

A literature search of PubMed and Embase was performed and from 595 identified articles, 34 papers were included in this review. There are several benefits of simulation teaching in paediatrics, including skill acquisition, improvement, maintenance, enhanced confidence, better understanding of human factors, improved teamwork skills and an opportunity to debrief as well as the potential for downstream improvements in patient outcomes. However, several challenges of simulation teaching for paediatrics were acknowledged, such as resource availability. Approaches to overcoming these challenges were proposed by the use of low-fidelity manikins, alternatives to standardised patients, the judicious use of simulation education, optimisation of student preparation for simulation sessions, the use of registrars as simulation facilitators and the utilisation of remote facilitation. With further research regarding the impact of simulation teaching on real-life clinical performance as well as methods to optimise its delivery, efficiency and cost-effectiveness, paediatric simulation teaching has considerable potential to enhance education for medical students in Australia.

Introduction

Simulation describes "*an artificial representation of a real-world process to achieve educational goals through experiential learning*" [1]. Simulation-based education was originally used in the 1970s by the National Aeronautics and Space Administration (NASA) in the United States to build teamwork skills and to reduce error to prevent airline crashes [2]. Simulation has since been used in other industries, such as the military, oil industry and healthcare [3]. Simulation-based teaching in healthcare places learners in lifelike environments where they experience scenarios that mimic real clinical encounters [4]. Simulation uses modalities such as low-fidelity and high-fidelity manikins and standardised patients. Fidelity describes the degree to which simulation replicates reality [5]. The term fidelity can be applied to manikins; low-fidelity manikins are basic unchanging models, whereas high-fidelity manikins are computer-based and can be programmed to demonstrate physiologic responses to the user, for example, breath sounds, pulses, and eye signs [6]. Standardised patients are individuals who are trained to portray an actual patient or illness [6].

Simulation allows learners to acquire and practice new skills without posing a risk to real patients. It is a well-established tool for teaching and learning in medicine, but has, to date, been predominantly used in postgraduate training programs in Australia [7]. There are no published data documenting the amount of simulation-based education used in paediatric teaching in Australia. Surveys of paediatric institutions in America and Switzerland reported paediatric simulation being used in 89% (n=71) and 66.6% (n=30) of the centres, respectively [5,7]. The purpose of this paper is to answer the question: could simulation teaching enhance the teaching of paediatrics to Australian medical students? In answering this question, the need for and benefits of simulation training in teaching paediatrics to medical students will be examined, the potential barriers to its implementation will be described and the recommendations for its use will be made.

Materials and Methods

A literature search of PubMed and Embase was performed on July 2nd 2017. Search terms were grouped under the broad themes of "simulation", "paediatrics" and "medical students". A full list of search terms is provided in Appendix 1. The reference lists of identified papers were reviewed to identify additional articles. The initial literature search identified 595 articles. The search was limited to English language publications. The articles were examined by two reviewers and the papers focusing on teaching in specialty paediatric training, nursing and allied health professions, or the use of simulation as an assessment tool were excluded. Studies from overseas were included, as few Australian studies have been conducted. A PRISMA diagram is included below to demonstrate the search strategy used (Figure 1). Subsequently, 34 papers were included for the literature review.

Results

Benefits of simulation education

Simulation education is an evolving teaching modality with potential benefits to both medical students and their future patients. Undergraduate medical education has previously been primarily delivered in the form of lectures and practical lessons. Simulation teaching provides an opportunity to apply knowledge to clinical scenarios in a safe and controlled environment [6,8-11]. Given that clinical environments are often busy, the provision of a facilitated debriefing following each scenario is not always afforded. Simulation enables identification and correction of errors as well as adaptation of behaviours to enable better care and clinical outcomes for patients [12]. Furthermore, a fundamental component of simulation education is the delivery of 'human factor training' in non-technical skills such as leadership, communication and prioritisation [8,9]. Simulation-based teaching also allows exposure to a broad range of clinical scenarios to address specific educational objectives [6,8,10,11]. Hence, simulation education has great potential for integration into medical curriculum worldwide.

Benefits of paediatric simulation teaching

There is now a growing body of evidence supporting the efficacy of simulation education as a teaching tool in the undergraduate paediatric curriculum. Paediatric simulation teaching demonstrates many benefits when compared with traditional forms of medical education. Traditional teaching is centred around a combination of time spent on a paediatric ward in a hospital setting, lectures, and tutorials. However, recent increases in medical student numbers in Australia have raised concerns about the system's ability to provide quality clinical placements [13]. In addition to this, opportunities to learn and practice skills on sick children are limited by ever more stringent restrictions [7]. At the completion of a medical program, the paediatric experience of two undergraduate students from the same university can vary greatly; for example, one student may have completed their paediatric rotation in a rural general hospital, while another completed theirs in a tertiary paediatric hospital. Thus, not all medical students will encounter patients with the same range of clinical conditions or experiences. Simulation education can be used to standardise undergraduate paediatric experience, ensuring all medical students are exposed to both common and rare presentations [6,10]. Thus, simulation education has a particular role to play in the teaching of paediatrics to medical students.

Increased student confidence

A small observational study by Hayes *et al*. [14] reported a 75% increase in medical student confidence in the management of paediatric emergencies following the introduction of simulation training. Similarly, in a study at John Hopkins University School of Medicine, the inclusion of simulation-based teaching in a paediatric rotation resulted in more than 95% of students feeling confident to see paediatric patients [10]. A further study by Whitt *et al*. [15] demonstrated statistically significant increases ($p<0.05$; Bonferroni correction, $p<0.006$) in student confidence and self-perceived ability in paediatric settings following three simulated patient encounters.

Improvements in knowledge and understanding

Paediatric simulation teaching facilitates improved understanding and identification of knowledge gaps through facilitated debriefs that address behaviours, skills and clinical decision making during the simulation [11,7,16]. In an observational study of the integration

of a high-fidelity simulator in a third-year paediatrics clerkship, 98% of students agreed this form of learning experience produced better understanding of clinical issues [8]. In the United States, students exposed to simulation also scored substantially higher on the National Board of Medical Examiners paediatric examination [10]. In an observational study undertaken with 56 final year medical students at Monash University, Malaysia, a significant knowledge gain was reported immediately following a simulation workshop [17]. Furthermore, knowledge retention has been shown to be greater following simulation compared traditional teaching methods [18]. A prospective cohort study undertaken by Drummond *et al.* [19] showed at six to twelve months following a paediatric cardiopulmonary arrest course, knowledge of 411 students attending simulation teaching was significantly higher ($p < 0.001$) than those attending traditional lectures.

Development of clinical skills

A prospective mixed methods study by Dudas *et al.* [10] showed a simulation-based curriculum improved medical student clinical performance with greater rates of history taking, performing examinations and procedural skills during their paediatric clerkship. Following simulation teaching, Objective Structured Clinical Examination (OSCE) scores are higher in students who receive this form of teaching compared to traditional methods [8,20,21]. A prospective cohort study of 385 students reported that students who undertook simulation training were more compliant with guidelines for paediatric resuscitation and ventilation skills were more effective [19]. Clinical skills acquired through simulation education transfer into better resident performance and improved patient care [4,19]. Thus, paediatric simulation training can be used as a powerful tool to improve patient outcomes.

Promotion of communication and teamwork

Current data indicates that preventable human factor errors, such as those brought about by communication problems within a team during an emergency, still occur in medical diagnosis and treatment [2]. Paediatric simulation teaching could potentially reduce these types of errors by allowing students the opportunity to practice working in inter-professional teams [2,22].

Student satisfaction

Paediatric simulation teaching is superior to traditional teaching methods with regards to student satisfaction and motivation [23-25]. Instructor enthusiasm and knowledge in paediatric simulation teaching is also rated highly by medical students [23]. An American prospective mixed-methods study evaluating a five-day long simulation-based clinical skills curriculum for 200 students reported that the time taken out of real clinical skills experiences, which was used for simulation-based teaching was considered, by students, as a worthwhile trade-off [10].

Challenges of paediatric simulation teaching

Despite its proven benefits, widespread implementation of simulation education in paediatric teaching of medical students has been impeded by several factors. A 2012 survey of 71 Pediatric Clerkship Directors in North America found the most commonly reported barriers to simulation-based education to be: available faculty time (66%, N=71), available time in clerkship (55%, n=71), funding considerations (54%, n=71) and lack of technical staff for simulation (32%, n=71) [6].

Resources

Health systems worldwide are facing funding shortages, including funding for medical education [26]. Simulation is resource intensive, involving costs of equipment, physical space, standardised patients and simulation education staff [3]. A simulation-based curriculum for medical students trialed by Dudas *et al.* [10] in the United States in 2014 cost $3600 per five-day session. This included the cost of space, staff support and disposable supplies. In a 2012 French study, comparing simulation with a traditional lecture, the cost of the simulation course was 24-times more expensive, but there is suggestion that the high cost of simulation may be offset by a reduction in adverse safety events and prevention of deaths [3,19].

Simulation teaching is time-consuming [8]. Competing and increasing demands of patient care, administration, research and professional development mean clinical staff, who often play the role of simulation facilitators, are often left with little time to support such teaching activities [8]. A potential solution to this problem is having a sustainable training program for simulation facilitators. Time constraints and competing priorities within the medical student paediatric curriculum itself have proved further barriers to the use of simulation education. Shortages of non-clinical simulation technicians further limit the utilisation of simulation in paediatric teaching of medical students and erode the quality of the educational experience delivered [27].

Poor student attitudes

The interactive nature of simulation education necessitates a willingness of students to participate in the process. Students with reluctance to participate were reported in two of the papers reviewed [7,21]. This is in contrast with the majority of studies where students valued and were satisfied with the simulation experience [11,18,19,23,24,28,29]. Where students were reluctant to participate, group dynamics were listed as a limiting factor in student engagement. Thus, attention by simulation facilitators to student interactions and areas for improvement in these relationships may have a favorable effect on student attitudes.

Retention of skills and knowledge

Another important consideration in simulation education is a decline in skills or knowledge learned over time. More than half of the knowledge acquired after a three-hour simulation-based neonatal resuscitation workshop in Malaysia was lost after one year [17]. A similar decline in knowledge was observed following a short course in simulation-based life-saving clinical skills delivered to third-year medical students in the United States [30]. Neither of these two studies compared the loss of knowledge following simulation teaching with traditional teaching methods. Repeat simulation sessions soon after initial exposure are therefore necessary to maintain students' competence in new skills [17]. It should be noted that a decline in skills or knowledge learned is also a concern for education provided through more traditional teaching methods.

Recommendations for the use of paediatric simulation education in the future

Given its demonstrated educational value, the incorporation of simulation teaching into medical student paediatric curricula should be a high priority for medical educators [4]. Use of low-fidelity manikins, alternatives to standardised patients and a focus on using simulation education judiciously may help to overcome challenges in the implementation of simulation. Shortages of simulation education staff may be overcome by optimising student preparation, using paediatric registrars as simulation tutors and delivering simulation teaching remotely.

Use of low-fidelity manikins

High-fidelity simulation scenarios require significant resources including expensive high-fidelity manikins, supporting software and instructors trained in the use of that particular software. Cost-effective delivery of simulation may be achieved by using low-fidelity manikins and alternatives to standardised patients. A Canadian study by Curran *et al.* [11] comparing low-fidelity and high-fidelity manikin simulators in the teaching of neonatal resuscitation concluded that there was no significant difference between the two groups in resuscitation program performance and teamwork competencies. Thus, low-fidelity manikins may present a cost-effective alternative to high-fidelity manikins in some situations.

Alternatives to standardised patients

The use of standardised patients is also resource intensive and includes recruitment, training, and paid employment [26]. Several studies have proposed and tested alternatives to standardised patients. An Austrian pilot program using trained medical students to deliver paediatric simulation training to their peers concluded that this was a feasible and low-cost option [28]. Another study comparing student satisfaction and learning efficacy in simulation training with standardised patients versus peer role play found superior results with peer role play, a low-cost tool which is relatively easy to put into practice [26]. Another alternative to standardised patients are child and adolescent actors, shown in one study to be effective in training medical students in complex interviewing skills, such as in the discussion of challenging mental health issues [31]. Since 2003, the University of Melbourne has used high-school students to provide simulation experiences to medical students and enhance teaching of adolescent medicine through its popular 'Learning Partnerships' program [32].

Judicious use of simulation education

Given the potential cost of simulation education, it must be used judiciously and efficiently alongside other teaching methods. As simulation teaching has been shown to be effective in developing skills and behaviours, it should be used when these are the focus of teaching, while traditional methods should be prioritised when knowledge is the focus [23]. While the opportunities afforded by simulation in paediatrics are endless, simulation fits particularly well with the teaching of paediatric emergencies. This is because critical events are uncommon and correct management leads to optimal outcomes [23]. *"Just six conditions make up 83% of acute paediatric attendances: difficulty breathing, febrile illness, diarrhoea, abdominal pain, rash and seizure"* [20]. It is therefore feasible to consider, for example, that a six-station simulation training package could be developed and included in the paediatric curriculum for medical students.

Optimising student preparation

Effective student preparation for simulation sessions, such as mandatory pre-reading, reduces simulation education staff workload and makes better use of time available for teaching [33].

Use of registrars as simulation facilitators

A 2012 study at the Indiana University School of Medicine found medical residents (a position roughly equivalent to an Australian registrar) to be as effective as experienced faculty in facilitating simulation debriefings [34]. Using registrars to oversee simulation experiences may ease pressure on more senior clinical staff, thereby allowing additional simulation sessions to be incorporated into medical student paediatric curricula [34]. However, the availability of registrars to assist in simulation facilitation will be influenced by time constraints and competing priorities as previously discussed.

Utilisation of remote facilitation

Most simulation facilities are based in major population centres. Although not all rural centres lack access to simulation facilities and educators, some do. There is, therefore, a risk that incorporating simulation education into a paediatric curriculum may disadvantage students studying remotely. Remote facilitation uses a system that enables bidirectional live video communication between students at a remote site and an educator at a simulation centre [27]. Using this system, simulation educators can observe students' performances and communicate with on-site staff and students [27]. A Japanese study in 2016 compared the effectiveness of remote versus on-site facilitation and found that improvement in teamwork performance was not significantly different between the two groups [27]. Remote simulation is feasible to conduct technically and financially and could be used to overcome geographical limitations in the delivery of paediatric teaching to medical students, such as for students undertaking rural rotations [27].

Areas for further research

We recommend simulation education to be promoted as a modern and powerful tool to teach paediatric medicine to medical students. Research is needed into the impact of simulation training on real-life clinical performance and confidence over time [20]. Further research is also required to clarify when and how to use simulation most effectively and efficiently [35].

Conclusion

This review of the current literature on paediatric simulation teaching is highly relevant to Australian medical students. The literature highlights a deficiency in volume and variety of clinical experience, as well as a lack of opportunities to debrief in traditional paediatric teaching, resulting in low student confidence in management of paediatric patients. Thus, there is a need for enhanced paediatric teaching in the form of simulation education. Paediatric simulation teaching is beneficial for medical students through promotion of clinical understanding and knowledge, identification of knowledge gaps and effective skill acquisition, improvement and maintenance. It also facilitates the development of teamwork, communication skills and repetitive practice in a safe environment. Furthermore, there is high student satisfaction regarding the use of this evolving method of teaching in medical education.

Nevertheless, the implementation of paediatric simulation into medical curricula has been impeded by time constraints, funding limitations and a lack of technical staff. These challenges can be overcome by the judicious use of paediatric simulation for targeted learning objectives, use of common and rare, but life-threatening scenarios, as well as teaching with low-fidelity manikins. Further avenues for overcoming challenges include utilisation of peers and high school students as standardised patients, provision of debriefing by registrars and remote teaching.

There is scope for further research regarding the influence of paediatric simulation teaching on real-life clinical performance, including the long-term retention of skills and confidence following graduation from medical school. With optimisation of efficiency and effectiveness, as well as further research and refinement of delivery, paediatric simulation teaching has great potential to enhance paediatric education for medical students throughout Australia.

Acknowledgements

The authors thank Dr. Gillian Laven for supervising the writing of this review article and for assistance with technical editing. We also thank the Adelaide Health Simulation and Skills Centre for introducing us to simulation education.

References

[1] Sharma J, Myers D, Dinakar C. Simulation in pediatrics. Mo Med [Internet]. 2013 [cited 2017 Jul 2]. Available from: http://www.omagdigital.com/article/Simulation+in+Pediatrics/1392555/0/article.html

[2] Gordon M, Darbyshire D, Baker P. Non-technical skills training to enhance patient safety: a systematic review. Med Educ. 2012;46:1042-54. doi:10.1111/j.1365-2923.2012.04343.x

[3] Clerihew L, Rowney D, Ker J. Simulation in paediatric training. Arch Dis Child Edu Pract Ed. 2016;101(1):8-14. doi:10.1136/archdischild-2015-309143

[4] McGaghie WC, Issenberg SB, Cohen ER, Barsuk JH, Wayne DB. Does simulation-based medical education with deliberate practice yield better results than traditional clinical education? A meta-analytic comparative review of the evidence. Acad Med. 2011;86(6):706-11. doi:10.1097/ACM.0b013e318217e119

[5] Stocker M, Laine K, Ulmer F. Use of simulation-based medical training in Swiss pediatric hospitals: a national survey. BMC Med Educ [Internet]. 2017 [cited 2017 Jul 6];17(104). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5473998/

[6] Vukin E, Greenberg R, Auerbach M, Chang L, Scotten M, Tenney-Soeiro R, et al. Use of simulation-based education: a national survey of paediatric clerkship directors. Acad Pediatr. 2014;14:369-74. doi:10.1016/j.acap.2014.04.001

[7] Stewart M, Kennedy N, Cuene-Grandidier H. Undergraduate interprofessional education using high-fidelity paediatric simulation. Clin Teach. 2010;7:90-6. doi:10.1111/j.1743-498X.2010.00351.x

[8] Ortiz N, Pedrogo Y, Bonet N. Integration of high-fidelity simulator in third-year paediatrics clerkship. Clin Teach. 2011;8:105-8. doi:10.1111/j.1743-498X.2011.00438.x

[9] Morrissey B, Jacob H, Harnik E, Mackay K, Moreiras J. Simulation in undergraduate paediatrics: a cluster-randomised trial. Clin Teach. 2016;13:337-42. doi:10.1111/tct.12442

[10] Dudas RA, Colbert-Getz JM, Balighian E, Cooke D, Golden WC, Khan S, et al. Evaluation of a simulation-based pediatric clinical skills curriculum for medical students. Simul Healthc. 2014;9(1):21-32. doi:10.1097/SIH.0b013e3182a89154

[11] Curran V, Fleet L, White S, Bessell C, Deshpandey A, Drover A, et al. A randomised controlled study of manikin simulator fidelity on neonatal resuscitation program learning outcomes. Adv Health Sci Educ Theory Pract. 2015;20:205-18. doi:10.1007/s10459-014-9522-8

[12] Fielder EK, Lemke DS, Doughty CB, Hsu DC, Middleman AB. Development and assessment of a pediatric emergency medicine simulation and skills rotation: meeting the demands of a large pediatric clerkship. Med Educ Online [Internet]. 2015 [cited 2017 Jul 2];20. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4666893/

[13] Jolly R. Medical practitioners: education and training in Australia [Internet]. Canberra ACT: Parliament of Australia; 2009 [cited 2017 July 6]. Available from: https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/BN/~/link.aspx?_id=4FB58821DB2B49F58743E7802D1C4ED3&_z=z

[14] Hayes A, Grimbley J, Williams JD. Is simulation an effective method for teaching paediatric emergencies to final year medical students? Arch Dis Child. 2017;102:A99. doi:10.1136/archdischild-2017-313087.246

[15] Whitt R, Toussaint G, Bruce Binder S, Borges NJ. Strengthening student communication through pediatric simulation patient encounters. J Educ Eval Health Prof [Internet]. 2014 [cited 2017 Jul 2];11(21). Available from: https://www.jeehp.org/DOIx.php?id=10.3352/jeehp.2014.11.21

[16] Coolen EHA, Draaisma JMT, Hogeveen M, Antonius TAJ, Lommen CML, Loeffen JL. Effectiveness of high fidelity video-assisted real-time simulation: a comparison of three training methods for acute pediatric emergencies. Int J Paediatr [Internet]. 2012 [cited 2017 Jun 22]. Available from: https://www.hindawi.com/journals/ijpedi/2012/709569/

[17] Lai NM, Ngim CF, Fullerton PD. Teaching medical students neonatal resuscitation: knowledge gained and retained from a brief simulation-based training workshop. Educ Health (Abingdon). 2012;25(2):105-10. doi:10.4103/1357-628.103457

[18] Curran VR, Aziz K, O'Young S, Bessell C. Evaluation of the effect of a computerised training simulator on the retention of neonatal resuscitation skills. Teach Learn Med. 2004;16(2):157-64. doi:10.1207/s15328015tlm1602_7

[19] Drummond D, Arnaud C, Thouvenin G, Guedj R, Grimprel E, Duguet A, et al. An innovative pedagogic course combining video and simulation to teach medical students about pediatric cardiopulmonary arrest: a prospective cohort study. Eur J Pediatr. 2016;175:767-774. doi:10.1007/s00431-016-2702-1

[20] Mathai SS, Joshi D, Choubey M. Bedside infant manikins for teaching newborn examinations to medical students. Indian Pediatr. 2017;54:208-10. doi:10.1007/s13312-017-1032-3

[21] Zundel S, Blumenstock G, Herrmann-Werner A, Trueck M, Schmidt A, Wiechers S. Undescended testis? How to best teach the physical examination. J Pediatr Urol. 2016;12:406.e1-406.e6. doi:10.1016/j.jpurol.2016.07.003

[22] Michael M, Abboudi H, Ker J, Khan MS, Dasgupta P, Ahmed K. Performance of technology-driven simulators for medical students – a systematic review. J Surg Res. 2014;192:531-43. doi:10.1016/j.jss.2014.06.043

[23] Bittencourt Couto T, Farhat SCL, Geis GL, Olsen O, Schvartsman C. High-fidelity simulation versus case-based discussion for teaching medical students in Brazil about pediatric emergencies. Clinics (Sao Paulo). 2015;70(6):393-9. doi:10.6061/clinics/2015(06)02

[24] Halaas GW, Zink T, Brooks KD, Miller J. Clinical skills day preparing third year medical students for their rural rotation. Rural Remote Health [Internet]. 2007 [cited 2017 Jul 6];7(4):788. Available from: http://www.rrh.org.au/articles/subviewnew.asp?ArticleID=788

[25] Cavalerio AP, Guimaraes H, Calherios FL. Training neonatal skills with simulators. Acta Paediatr. 2009;98(4):636-9. doi:10.1111/j.1651-2227.2008.01176.x

[26] Bosse HM, Nickel M, Huwendiek S, Schultz JH, Nikendei C. Cost-effectiveness of peer role play and standardised patients in undergraduate communication training. BMC Med Educ [Internet]. 2015 [cited 2017 Jul 2];15(183). Available from: https://bmcmededuc.biomedcentral.com/articles/10.1186/s12909-015-0468-1

[27] Ohta K, Kurosawa H, Shiima Y, Ikeyama T, Scott J, Hayes S, et al. The effectiveness of remote facilitation in simulation-based pediatric resuscitation training for medical students. Pediatr Emerg Care. 2016;0(0):1-6. doi:10.1097/PEC.0000000000000752

[28] Wagner M, Mileder LP, Goeral K, Klebermass-Schrehof K, Cardona FS, Berger A, et al. Student peer teaching in paediatric simulation training is a feasible low-cost alternative for education. Acta Paediatr. 2017;106:995-1000. doi:10.1111/apa.13792

[29] O'Keefe M, Sawyer M, Roberton D. Medical students taking the role of the mother in paediatric interview evaluation. Med Educ. 2004;38:294-301. doi:10.1046/j.1365-2923.2004.01768.x

[30] Ander DS, Heilpern K, Goertz F, Click L, Kahn S. Effectiveness of a simulation-based medical student course on managing life-threatening medical conditions. Simul Healthc. 2009;4(4):207-11. doi:10.1097/SIH.0b013e3181a9dd84.

[31] Brown R, Doonan S, Shellenberger S. Using children as simulated patients in communication training for residents and medical students: a pilot program. Acad Med. 2005;80(12):1114-20

[32] Cahill H, Coffey J, Sanci L. 'I wouldn't get that feedback from anywhere else': learning partnerships and the use of high school students as simulated patients to enhance medical students. BMC Med Educ [Internet]. 2015 [cited 2017 Jul 2];15(35). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4355139/

[33] Lehmann R, Bosse HM, Huwendiek S. Blended learning using virtual patients and skills laboratory training. Med Educ. 2010;44:521-2. doi:10.1111/j.1365-2923.2010.03653.x

[34] Cooper DD, Wilson AB, Huffman GN, Humbert AJ. Medical students' perception of residents as teachers: comparing effectiveness of residents and faculty during simulation debriefings. J Grad Med Educ. 2012;486-9. doi:10.4300/JGME-D-11-00269.1

[35] Cook DA, Hatala R, Brydges R, Zendejas B, Szostek JH, Wang AT, et al. Technology-enhanced simulation for health professions education: a systematic review and meta-analysis. JAMA. 2011;306(9):978-88. doi:10.1001/jama.2011.1234

Appendix 1

PubMed search: (Simulation training [MH] OR Simulat* [TIAB] OR Vignette* [TIAB]) AND (Pediatrics [MH] OR Adolescent [MH] OR Child [MH] OR Infant [MH] OR Paediatric* [TIAB] OR Pediatric* [TIAB] OR Child* [TIAB] OR Infant* [TIAB] OR Neonat* [TIAB] OR Adolescen* [TIAB] OR Teen* [TIAB] OR Youth* [TIAB]) AND (Students, medical [MH] OR Schools, medical [MH] OR Medical student* [TIAB] OR MBBS [TIAB] OR MD [TIAB] OR Undergraduate medicine [TIAB] OR Medical school [TIAB] OR Clerkship [TIAB])

Embase search: (Simulation/exp OR Simulat*:ab,ti OR Vignette*:ab,ti) AND (Pediatrics/exp OR Adolescent/de OR Child/de OR Infant/exp OR Paediatric*:ab,ti OR Pediatric*:ab,ti OR Child*:ab,ti OR Infant*:ab,ti OR Neonat*:ab,ti OR Adolescen*:ab,ti OR Teen*:ab,ti OR Youth*:ab,ti) AND (Medical student/de OR medical school/de OR Medical student*:ab,ti OR MBBS:ab,ti OR MD:ab,ti OR Undergraduate medicine:ab,ti OR Medical school:ab,ti OR Clerkship:ab,ti)