Review Article

Challenges and Opportunities in Teaching and Training Pediatric Cardiac Critical Care in Developing Countries: A Narrative Review

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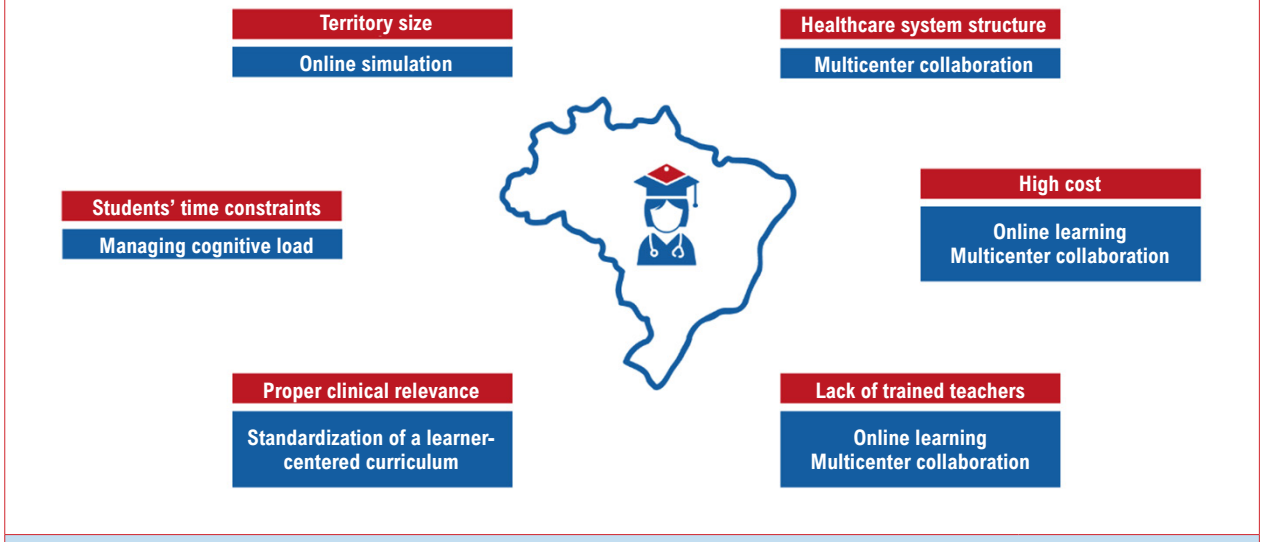
Central Illustration: Challenges and Opportunities in Teaching and Training Pediatric Cardiac Critical Care in Developing Countries: A Narrative Review



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Abstract

Congenital heart disease (CHD) is a public health issue in developing countries. Effective teaching and training are vital for healthcare professionals to provide adequate care for critically ill cardiac children, but there are many obstacles to adequately training a cohort of healthcare professionals in low- and middle-income countries (LMIC), where education practice is not always aligned with current education evidence. Work overload, time constraints, language, and the healthcare structure itself hinder standardization of an optimal training process for this highly complex scenario. This narrative review aims to explore how current teaching methodologies may help overcome challenges in pediatric cardiac critical care (PCCC) education, thus helping clinical practice, with a special focus on developing countries and the Brazilian scenario.

Keywords

Medical Education; Teaching; Congenital Heart Defects; Critical Care; Telemedicine.

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Introduction

Congenital heart disease (CHD) is a public health issue in developing countries. It is estimated that 75 out of every 1000 newborns have some form of heart disease, with the most severe forms accounting for 0.6% of live births. The vast majority of them are born in developing countries,[1,2] and developmental indexes, such as global mortality under 5 years of age, gross domestic product per capita, and health expenditure per capita have been shown to correlate with poorer results after congenital cardiac surgery, adding another layer of complexity to this problem.[3] The Global Burden of Disease study showed that the rank of CHD increased from 17th to 11th in low-socio-demographic index countries between 1990 to 2017, and among the 261,247 deaths caused by CHD in 2017 worldwide,

180,624 were infants, with the majority occurring in countries with lower socio-demographic index.[4] Health system issues such as poor access, lack of adequately trained professionals, and limited technical resources are obstacles to proper care of this population in low- and middle-income countries (LMIC). Healthcare structures in developing countries often have many small centers that run in parallel and mixtures of private and public health services, making it difficult to achieve better results, since center volume has also been previously shown to correlate with surgical outcomes.[5] In addition, proper care for these complex children requires specialized training that relies on the integration of multidisciplinary knowledge from pediatric cardiology, pediatric critical care, and neonatology, as well as behavioral skills for effective teamwork. Currently, children with cardiac issues outnumber specialists.[6–11] Moreover, general pediatricians' knowledge of pediatric cardiology may often be insufficient for optimal management of this population.[12–14] These facts, combined with the heterogeneous distribution of medical subspecialists,[15] make it essential to train professionals involved in the care of critically ill cardiac children.

Nevertheless, developing a trained cohort of providers is particularly difficult in LMIC, and the best way to properly train professionals for the care of critical cardiac children in LMIC is still knowledge gap due to the scarcity of research in the field (Table 1). Education practice is not always based on current evidence for best practices, and passive knowledge transmission and uni-professional teaching are still the rule. Many professionals work in more than one center, which makes time and financial constraints obstacles to proper training. Language is also a barrier, as most international initiatives that are available online cannot be used in non-English speaking countries. Healthcare structure is another obstacle; there are many low-volume centers which may not be able to offer enough patient exposure for adequate training. Moreover, heterogeneous distribution of training centers within countries with large territories may limit access to proper training, and a standardized curriculum has yet to be developed or adapted. In addition, late presentation of CHD is more common in LMIC, due to lack of diagnosis and healthcare access, and usual training may not adequately prepare providers to deal with these patients (Central Illustration). This paper aims to investigate how these obstacles can be overcome in LMIC, with a special focus on the Brazilian scenario, looking into the literature on teaching and training in pediatric cardiac critical care (PCCC) from the perspective of adult-learning theory. For that purpose, we searched the following databases: Pubmed, Wiley, Ovid, and Google Scholar; the terms used include "pediatric cardiac intensive care" and ("teaching" or "training" or "curriculum" or "medical education"). We also performed a manual search of references from original studies and review articles to identify any additional relevant studies.

The subspecialty's history

PCCC is a subspecialty characterized by high complexity and a variety of distinct physiologies and anatomies. Over recent decades, there has been a significant improvement in survival rates within this field. Heart conditions that were once considered lethal can now be palliated through univentricular approaches, and the expansion of mechanical circulatory support and pediatric heart transplantation has also significantly contributed to increased life expectancy in this population. Factors influencing these improved outcomes include a better understanding of various physiologies, advancements in surgical techniques and critical care, and specialized therapies provided by qualified professionals in multidisciplinary units dedicated exclusively to this population, following the example set by cardiac critical care in the adult population.[16–19] Units exclusively focused on critically ill cardiac children have shown a notable impact on mortality and morbidity indicators, such as the duration of mechanical ventilation and surgical site infection rates.[20,21] In a North American study, Horak and colleagues observed a higher rate of long-term mechanical circulatory support in units dedicated to managing pediatric cardiogenic shock, reflecting the need for high specialization in managing this therapeutic tool.[22]

Currently, there is significant heterogeneity in the profiles of medical professionals responsible for caring for this population, even within units dedicated exclusively to PCCC.[23] The optimal academic training pathway has been a subject of extensive discussion in the literature. Multiple manuscripts have addressed the question of which professions are best qualified to care for this population, a significant debate between pediatric cardiologists and pediatric intensivists.[24–28] The most recent answer has come from publications that emphasize that the pathway to the subspecialty may vary but should encompass competencies from both areas.[29–31] Dual board certification in pediatric critical care and pediatric cardiology fully covers both knowledge areas but is a costly and time-consuming route. Alternatives include initial training in one subspecialty, followed by an additional year that integrates competencies from the adjacent subspecialty. This format is already common in North America, with 26 additional year programs in PCCC.[32–34] Determining the expected competencies and entrustable professional activities for these professionals, regardless of their basic training, is essential to ensure proper care for these children. For this reason, there has been growing international momentum in recent years to officially establish the subspecialty before regulatory bodies.[32,35–37] In Brazil, there are few specialized centers with a high patient volume, and surgeons, intensivists, and cardiologists provide perioperative care at many smaller centers. Moreover, there is no formal curriculum standardization or official certification for the subspecialty in Brazil. Only a few centers offer this additional year of training in PCCC, with varying admission criteria and curricula, and many professionals who care for this population in intensive care units (ICUs) learn from practice and have not undergone proper formal training.

Applying adult learning theories to improve PCCC training in LMIC

Considering the specificities of PCCC training, determining the best way to operationalize skill-based training for this subspecialty has been a focal point of study over the last decade. Balancing work hours with the increasing amount of technical medical knowledge required for adequate care of this population can be challenging. The swift evolution of knowledge, which has improved child survival rates, has not

Table 1 – Examples of education and training in PCCC

LMIC' experiences					
Study, year	Design	Population	Setting	Teaching methods	Findings
Maheshwari et al., 2015[48]	Prospective cohort study	231 pediatric cardiology trainees	Online platform from India	Video lessons Online synchronous lessons Library Self-assessment tests	Improvement in self-reported knowledge and skills
Oliveira et al., 2017[52]	Prospective cohort study	62 healthcare professionals	Online platform from Brazil/ Portugal	Video lessons	Knowledge improvement assessed via pre- and post-tests
Borim BC et al., 2017[47]	Prospective single-center cohort study	29 nursing technicians	Pediatric cardiac intensive care unit in South America	Video lessons	Knowledge improvement assessed via pre- and post-tests
Emani et al., 2018[60]	Prospective single-center cohort study	23 members of a multidisciplinary team	Pediatric cardiac intensive care unit in Southeast Asia	Interactive discussions Simulation-based training	Improvement in team dynamics Decreased time to intervention in simulation scenarios
Pilan et al., 2022[44]	Retrospective single-center study	68 members of a multidisciplinary team	Pediatric cardiac intensive care unit in South America	Simulation-based training	Improvement in self-reported knowledge, skills, and comfort related to resuscitation Decreased mortality for ECMO patients
High-income countries' experiences					
Study, year	Design	Population	Setting	Teaching methods	Findings
Allan et al., 2010[61]	Prospective single-center cohort study	182 members of a multidisciplinary team	Pediatric cardiac intensive care unit in North America	Game play Didactic lessons Simulation-based training	Improvement in preparedness to participate in emergency care Diminished levels of anxiety in entering a code event
Kane et al., 2011[73]	Prospective single-center cohort study	65 nurses	Pediatric cardiac intensive care unit in North America	Simulation-based training	Improvement in self-reported knowledge, skills, and comfort related to resuscitation
Figueroa et al., 2013[74]	Prospective single-center cohort study	37 members of a multidisciplinary team	Pediatric cardiac intensive care unit in North America	Didactic lessons Simulation-based training	Improvement in team dynamics Improvement in confidence in participating in code events
Su et al., 2014[75]	Retrospective single-center study	Multidisciplinary team	Pediatric cardiac intensive care unit in North America	Simulation-based training	Decreased extracorporeal cardiopulmonary resuscitation times in real patients
Campbel et al., 2015[76]	Retrospective single-center study	7 nurses	Pediatric cardiac intensive care unit in North America	Didactic lessons Simulation-based training	Improvement in self-reported knowledge, skills, and comfort related to resuscitation
Villa et al., 2017[77]	Retrospective single-center study	Members of a multidisciplinary team	Pediatric cardiac intensive care unit and emergency department in North America	Simulation-based training	Identification of latent safety threats that led to practice changes

Brown et al., 2018[42]	Prospective multicenter interventional study	30 nurses	13 pediatric cardiac intensive care units in North America	1 day simulation-based educational training boot camp	Knowledge improvement assessed via pre- and post-tests Decreased time to intervention in simulation scenarios
Di Nardo et al., 2018[43]	Retrospective single-center study	Multidisciplinary team	Pediatric intensive care unit in Europe	Simulation-based training	Decreased time to manage emergencies on ECMO in real patients
Tretter et al., 2020[46]	Retrospective study	Global audience	Online platform	Video lessons	Descriptive study of the implementation of Heart University
Ralston et al., 2021[64]	Cross-sectional study	6 attending physicians	Pediatric cardiac intensive care unit in North America	Virtual simulation	Students' evaluation of the experience was positive
Nater et al.,2023[78]	Prospective single-center cohort study	121 members of a multidisciplinary team	Pediatric cardiac intensive care unit in North America	Simulation-based training	Improvement in self-reported knowledge, skills, and comfort related to resuscitation

ECMO: extracorporeal membrane oxygenation; LMIC: low- and middle-income countries.

been paralleled by an increase in time dedicated to clinical teaching and learning. Adding to this complexity, skills like leadership, conflict resolution, and teamwork are vital in such a multifaceted clinical setting, amplifying the required expertise for proficient professional practice.[38] Therefore, effective educational tools in this area should address time constraints, scheduling flexibility, clinical relevance, and accessibility, both financially and technologically.[39–41] Various training methods have shown promise in addressing these dilemmas. Face-to-face or online theoretical courses, isolated realistic simulation events, and intensive "boot camp" training styles are among the tools that have demonstrated feasibility, acceptance, and effectiveness in studies.[42–44]

Knowledge updating is vital in healthcare professions, and the recent proliferation of hybrid or exclusively online teaching tools has not only enhanced connections among healthcare professionals but also expanded opportunities for collaborative learning. Active teaching and learning methodologies share common goals: engaging adult learners within their social context, fostering both teamwork and social engagement, and integrating learners into a team. This ensures not only the acquisition and understanding of a concept but also its analysis, critical evaluation, and application in clinical practice, which are processes that align with Bloom's taxonomy of higher-order thinking skills (Figure 1).[45]

Courses disseminating theoretical content are vital for PCCC training, as they may provide the basis for these higher-order skills and consequent better clinical practice. Asynchronous online learning allows students flexibility and self-pacing while preserving synchronous teacher-student interactions for knowledge construction rather than mere information transmission. Exemplary online courses and learning tools in basic pediatric cardiology have been described for both developing countries and a global landscape of multi-institutional collaboration.[46–49] Successful examples using online lessons to provide basic knowledge for professionals in LMIC have been published. An initiative in India focused on training pediatricians in pediatric cardiology, involving 231 students over 4 years, proved effective in enhancing professionals' confidence and clinical skills.[48] Although the language barrier mandates adaptations of these tools for use in Brazil, successful examples of the application of online tools to help learning and clinical management of patients within the country have been described. During the COVID-19 pandemic, the use of online intensive care tools and a tele-ICU program enabled the training of several healthcare professionals, as well as the remote clinical follow-up of critically ill patients admitted to ICUs throughout Brazil's vast territory.[50,51] In the pediatric cardiology field, a national study demonstrated the effectiveness of an asynchronous online course in basic pediatric cardiology training for 62 healthcare professionals, mainly pediatricians and neonatologists, in the Northeast Region of Brazil through an online asynchronous course based on video lessons that were able to provide knowledge, as shown by an increase from pre- to post-test average scores.[52]

Andragogy, according to Knowles, "the art and science of helping adults learn," is defined by six fundamental principles: the learner's need to know, preference for self-directed learning, the existence of learner's prior experiences, the adult's readiness to learn, problem-solving orientation, and motivation to learn.[53] Adult learners are independent, capable of self-direction, and interested in knowing in advance what they will learn, how they will learn it, and why it is essential.[54,55] The signification of the teaching-learning process is integral to meaningful adult education, and feeling acknowledgment is crucial. In an interesting example of this feature, Silva and colleagues showed how addressing feelings related to knowledge gaps in interpreting electrocardiograms before teaching may be an effective strategy to nurture this signification.[56] Structuring a standardized curriculum for PCCC training has been a multicenter effort in North America

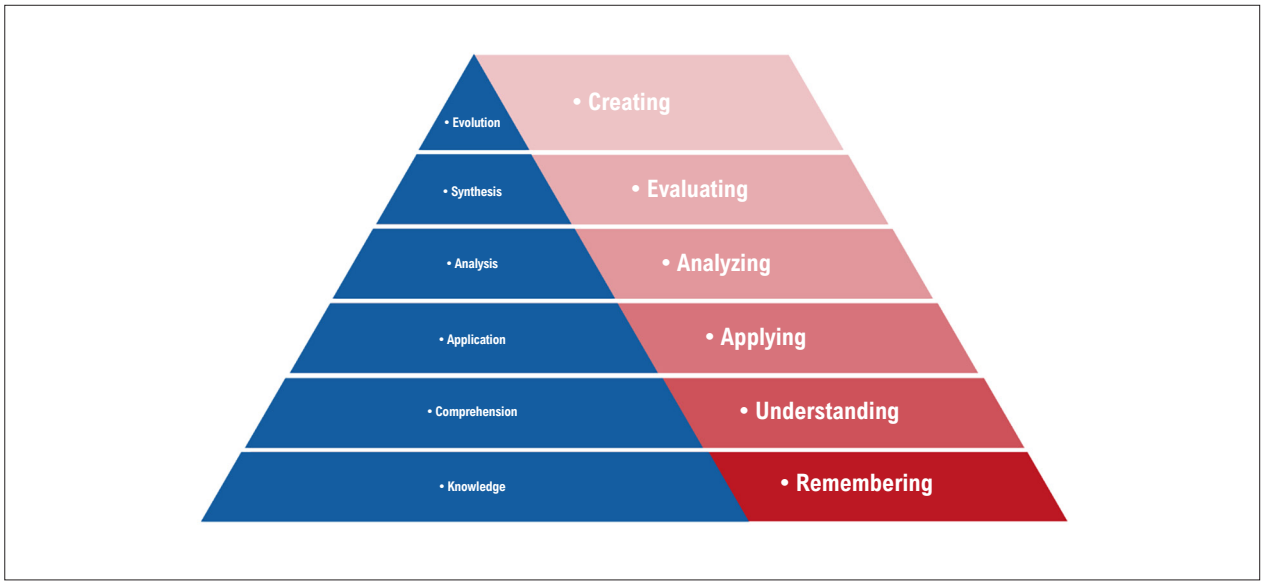

Figure 1 – *Bloom's Taxonomy.*[45]

and a step towards better teaching for these fellows.[29–31] A standardized curriculum helps the learner know in advance what they will learn and how they will learn it, which are crucial features for an adult learner. Also, it may provide the student with guidance for what will be expected of them in the form of entrustable professional activities that the trainee is expected to perform by the end of training. There is currently no standardized curriculum for LMIC and no data about how centers that have advanced fellowship structure their programs. However, instead of simply adopting the North American curriculum, considerations should be made as how to better adapt it to the LMIC scenario, including training for managing late presentation cases and in lower resource situations.

Kolb's learning theory states that adult learning occurs in a four-phase experiential cycle (Figure 2). From this perspective, adult learning always begins with prior knowledge and is driven by concrete experiences, leading learners to seek alternatives or solutions to identified problems; therefore, any strategy that aims at education and training in the field must start by exploring students' concrete experiences and current knowledge to build on top of them. Simulation-based education is an example of how this theory can be applied; concrete and practical experiences can be provided in a controlled environment, enabling learning from errors and knowledge gaps without jeopardizing patient safety, which is especially crucial given the limited physiological reserve of this patient population. A recent systematic review highlighted the benefits of simulation and virtual reality in cardiology education, emphasizing patient safety while imparting knowledge.[57,58] In PCCC, successful examples have illustrated effective training for medical teams, nursing staff, and the entire multidisciplinary team in both developed and developing countries.[42,59,60] Theoretical learning complements behavioral learning, enhancing self-confidence and reducing anxiety during emergency care participation within a complex team setting.[61] A multi-institutional collaboration showcased how a simulation-based boot camp for nurses could enhance their technical knowledge and self-confidence.[42] However, potential barriers to implementing simulation in LMIC include costs, specific infrastructure needs, adequate professional training for simulation execution and debriefing, lack of awareness regarding simulation benefits, and psychological resistance.[52] Virtual simulation offers potential solutions to Brazil's vast territorial obstacles in providing adequate care to pediatric cardiac patients, although this is a model that has yet to be tested in practice. Immersion in a virtual environment can offer realistic experiences, augment knowledge, motivate learners, and boost their confidence in patient care.[62,63] Although it is currently used infrequently in PCCC, optimism surrounds its potential.[64] A successful example of the positive impact of simulation in LMIC was published by Emani et al., who assessed the effect of simulation on team dynamics and performance in 23 healthcare providers in a pediatric cardiac ICU in Southeast Asia via a training program based on multimedia lessons, interactive discussion sessions and four 1-hour scenario simulation sessions delivered over a 5-day period. Participants noted significant improvement in team dynamics and video analysis revealed a decrease in time to intervention and significant increase in frequency of closed-loop communication because of simulation training, showing that this is a feasible tool in LMIC.[60]

Time constraint issues are another concern. In today's reality, the overwhelming load of information can hinder medical adult education. Sweller's cognitive load theory, which originated in the 1980s, remains relevant in this scenario,[65] offering insights to optimize the teaching-learning process. Cognitive load is categorized into intrinsic, extrinsic, and effective (Figure 3). Intrinsic load pertains to the complexity of the information; extrinsic load is unrelated to the task, and effective load refers to the effort required to learn the task. Hence, educators should manage intrinsic load, optimize effective load, and minimize extrinsic load. Strategies

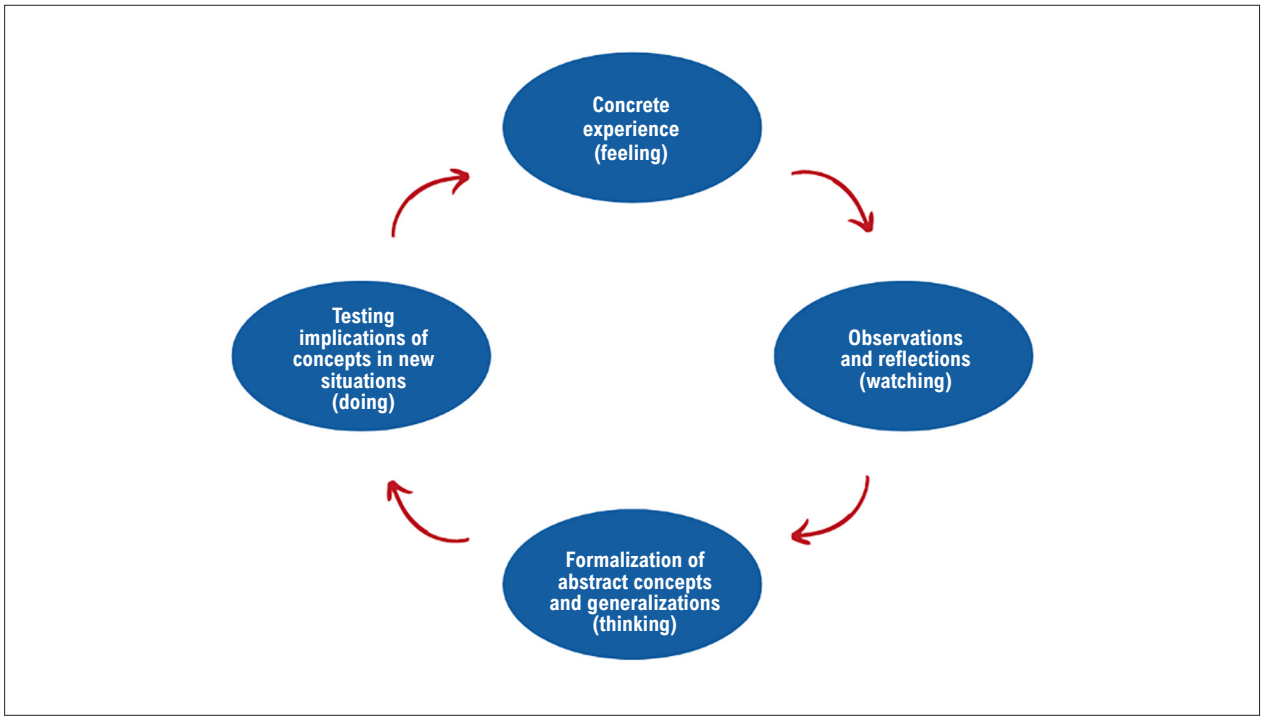

Figure 2 – *Kolb's Learning Cycle.*

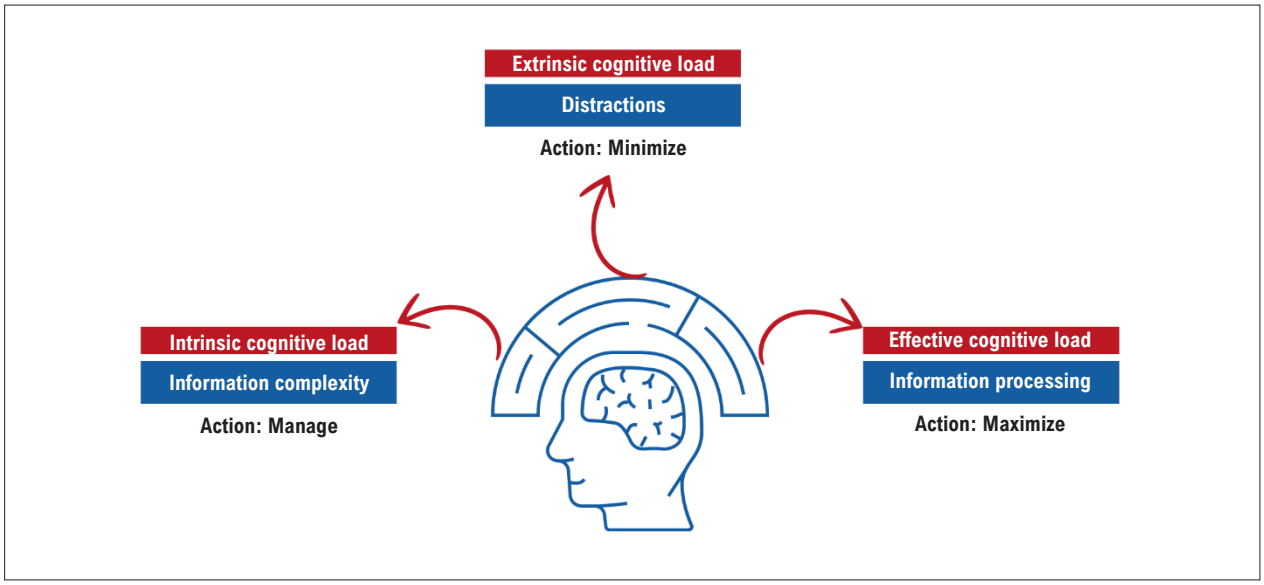

Figure 3 – *Managing cognitive load according to Sweller's Theory.*[65]

to reduce extrinsic load involve purposeful tasks integrating diverse information sources and minimizing redundancy. Managing intrinsic load entails progressively presenting knowledge complexity and transitioning tasks from low to high fidelity based on learners' knowledge. Effective load optimization involves using varied tasks, applying contextual interference, and prompting learners to explain learned topics.[66] Managing cognitive load in the setting of limited time is key for success. Understanding Sweller's cognitive load theory may help develop a program that optimizes time and resources. An interesting example is the SimZones concept, where progressive complexity-based learning allows for cognitive load management.[67]

Optimizing time and human resources is crucial for teaching PCCC in LMIC, since many healthcare providers work in more than one center, and there is rarely a protected

teaching time. Collaboration among different centers for teaching and training these fellows may also optimize time and human resources and help mitigate the workload. Examples of collaboration include structuring a standardized curriculum that addresses the particularities of PCCC in LMIC (such as late diagnosis), shared online lectures, virtual simulations, and elective rotation that allows fellows to be exposed to practical training in different centers. In addition, online tools such as tele-ICU consultation and online courses are a possible way to overcome challenges posed by the continental size of Brazilian territory and assist clinical practice.[68–70] The only national initiative published in the field of PCCC outlined a continuous education program developed in a similar fashion, including a virtual learning environment allowing access to video classes and pre- and post- training theoretical evaluation questionnaires. The course enrolled 24 nursing technicians, and progress in knowledge was verified by an increase in the average test score before and after the lessons. The course was well-received by students, with high satisfaction rates, and 90% of the students showed interest in the use of technological training resources.[47]

Finally, twinning centers from different economic backgrounds has also been shown to be an effective way to improve personnel skills and outcomes such as surgical site infection.[69,71,72] These partnerships have the beneficial effects of knowledge transmission through exchange programs and visits to reference centers, in a train-the-trainers model. Another way these partnerships have helped disseminate knowledge is through clinical support and continuous education, through both weekly online rounds and scheduled online lectures. Visits to the developing country center from its twin hospital staff are also an opportunity for theoretical and practical training.

Conclusion

Training healthcare professionals involved in the care of critically ill cardiac children is an essential step for establishing a better clinical practice, but it may be daunting in LMIC. These challenges may be overcome by means of collaboration between centers and the application of adult learning theory. Improving training quality can help enable these professionals to acquire and maintain the necessary knowledge, skills, and competencies to provide high-quality care to critically ill pediatric cardiac patients and their families.

Author Contributions

Conception and design of the research: Campos CV, Carvalho CRR; acquisition of data, analysis and interpretation of the data and writing of the manuscript: Campos CV; critical revision of the manuscript for intellectual content: Carvalho CRR.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

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Ethics Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors.

Use of Artificial Intelligence

The authors did not use any artificial intelligence tools in the development of this work.

Availability of Research Data

The underlying content of the research text is contained within the manuscript.

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