

CASE-STUDIES, PROBLEM BASED LEARNING AND SIMULATIONS IN BIOMEDICAL TEACHING – A LITERATURE REVIEW

APRENDIZAGEM BASEADA EM CASOS, PROBLEMAS E SIMULAÇÕES NO ENSINO DAS PROFISSÕES BIOMÉDICAS- UMA REVISÃO DA LITERATURA

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Resumo

Este artigo pretende sistematizar a evidência disponível sobre o uso e aplicação de CBL, PBL e SBT no ensino das profissões biomédicas, bem como analisar, diferenças significativas publicadas em estudos que versam a avaliação e eficácia destas abordagens pedagógicas na promoção da aprendizagem e do pensamento de ordem superior. O estudo baseia-se numa revisão sistemática de artigos e atas de congressos, publicados entre 1990 e 2011 em várias bases de dados. O nosso estudo revela que a principal área biomédica de aplicação de CBL, PBL ou SBT é a Medicina, seguida da Farmácia e finalmente da Enfermagem e Tecnologias da Saúde em proporções semelhantes. Geralmente, os estudos são concordantes no que diz respeito às vantagens de CBL, PBL e SBT comparativamente com o ensino tradicional, porém não existe evidência que sustente a eficácia comparativa da aprendizagem entre as três abordagens. As principais conclusões mostram que, embora as situações apresentadas sejam, em geral, casos de sucesso, cautela deve ser exercida quando se pretendem generalizar os resultados sobre diferenças significativas na aprendizagem e desenvolvimento do aluno, pois não existem estudos controlados a longo prazo. Também as perspetivas e atitudes dos estudantes em relação a CBL, PBL ou SBT são, em geral, positivas. Não obstante, é de crucial importância, o desenvolvimento de uma investigação mais consistente neste campo, suportada por estudos longitudinais e amostras com número superior às retratadas.

Palavras Chave: *Case Based Learning; Problem Based Learning; Simulation Based Training; Educação Biomédica.*

Abstract

This paper aims to review the use and application of CBL, PBL and SBT in biomedical education, as well as to review significant differences found in studies trying to assess the effectiveness of these pedagogical approaches in promoting learning and higher order thinking. Our research method was a systematic search and review of published journal articles and conference proceedings, between 1990 and 2011 in several databases. The study shows that the main area where we can find CBL, PBL or SBT is the Medical field, followed by Pharmacy, and Nursing and Allied Health in similar proportions. Generally, studies agree when referring the advantages of CBL, PBL and SBT regarding traditional teaching. There is however a lack of evidence when comparing learning effectiveness among the three approaches. The main conclusions show that although the situations presented are, in general, success cases, one must constrain in making generalized affirmations regarding significant difference in student learning and development, because no long term controlled studies have been conducted. Students' perspectives and attitudes towards these learning approaches are, in general, positive. However it seems important to develop more consistent research in this field, namely, longitudinal studies with larger samples.

Key words: *Case Based Learning; Problem Based Learning; Simulation Based Training; Biomedical Education.*

Introduction

Nowadays, learning a biomedical profession is an increasing challenge. The student is required to develop a vast range of intellectual, visual and manual skills, to take into account large amounts of factual information and to practice technical and technological procedures. Apart from traditional texts, lectures and self-guided individual learning, biomedical educators are encouraged to find and implement ways to promote higher order thinking, collaborative learning and to increase students' motivation (Jesus, Cruz, & Gomes, 2011). One way of achieving these objectives, is to complement traditional learning methods with the development and implementation of Case Based Learning (CBL), Problem Based Learning (PBL) or Simulation Based Training (SBT), supported in real life situations. The incorporation of real problems in biomedical education is seen as an effort to prepare future health professionals to meet the challenging demands of the profession, in particular, the provision of quality patient care. The findings of this methodology can be traced back to Dewey (1997), an early educational philosopher, who suggested that, students should be presented with real life problems and then, helped to discover the information required to solve them. Furthermore, Dewey encouraged reflection as a process that should be used when problem solving. The author recognized that we can "reflect" on a whole host of things in the sense of merely "thinking about" them; however, logical or analytical reflection can take place only when there is a real problem to be solved (Cisneros, Salisbury-Glennon, & Anderson-Harper, 2002). McMaster University recognized the importance of Dewey's axiom for medical education, and created a curriculum that applied the PBL approach to teach medical students (Neufeld & Barrows, 1974). At this point we should cite Barrows (1986), who argued that, "the term problem-based learning must be considered a genus for which there are many species and subspecies." In the PBL approach developed at McMaster University, students are first presented with the patient's problem. Next, the learners engaged in several processes, like hypothesis generation, data gathering, data analysis and decision-making, while synthesizing basic science and clinical information, in an effort to offer some potential diagnoses and courses of treatment for the patient's problem (Cisneros et al., 2002). In PBL (and other similar approaches like CBL), instead of a lecturer, we have an expert tutor or facilitator to guide the problem-solving process. All methodologies regarding real problems, stand in contrast to a more traditional approach to learning and instruction. They promote learner-centered, small group, interactive learning experiences, instead of large group, didactic, teacher-centered instruction. Professors facilitate or tutor, rather than lecture. As such, students are free to pursue determined learning issues, both collectively or individually, in contrast to students in more traditional curricula who might focus on identifying what material the professor will include on the exam (Cisneros et

al., 2002). Finally, the assessments in PBL typically include performance-based and self-reflective assessments, while traditional approaches to instruction often emphasize multiple choice, objective tests (Evensen, Salisbury-Glennon, & Glenn, 2001). With these models of instruction, it is expected that students readily re-organize and apply knowledge in response to various situational demands. To attain this flexibility, students must understand the problems in their full complexity and reorganize them, several times, to observe how shifts in variables and goals alter the outcomes. How well one can perform at this level, is a function of both the way knowledge is represented and the processes that operate on those mental representations. This perspective can be supported in Cognitive Flexibility and Social Constructivism learning approaches.

Cognitive Flexibility Theory

The Cognitive Flexibility Theory (CFT) is a conceptual model of instruction for the design of learning environments, based on cognitive learning theory (Mendes, Mosley, & Counsell, 2001). Its intent is to facilitate the acquisition of advanced and complex knowledge and to serve as the basis for expertise in complex and poorly structured (known as 'ill-structured') knowledge domains (R. Spiro, Feltovich, Jacobson, & Coulson, 1992). According to Spiro et al. (1992), all domains which involve the application of knowledge to unconstrained, naturally occurring situations (cases), are ill-structured. Examples include, history, literary interpretation, medicine (Spiro, 1992), and relatable biomedical areas (Coulson, Feltovich, & Spiro, 1997). Even in well-structured knowledge domains such as basic arithmetic, the process of application (applying arithmetic) to solve "real-life" problems is also poorly structured (Mendes et al., 2001). According to Jacobson (1994), the CFT asserts that students who develop "flexible representations of knowledge" will be more able to adapt it to a wider variety of problem settings. CFT supports the use of real based scenarios to promote learning of abstract concepts instead of learning facts that are removed from their context. This theory argues that presenting information from different perspectives and representations, stresses the complexity of knowledge over the isolation and decontextualization and involves the learner in the construction of new knowledge via problem-solving tasks rather than the recitation and memorization of facts and principles (Jacobson & Spiro, 1993) (Jacobson, 1994)(Oliver, 1997).

The main principles of CFT can be listed as follows (R. Spiro et al., 1992):

- Instruction should reflect the complexity that faces practitioners, rather than the treating of domain problems as simple, linear decision-making processes. As such, CFT emphasizes interconnectedness and avoids oversimplifying instruction.
- CFT also gives emphasis to case-based instruction, rather than basing instruction on a single example or case. It is important that a variety of cases be used to illustrate the content domain.

- CFT supports context-dependent knowledge, best acquired in relevant situations that are likely to be met by the student as a practitioner.

When compared to traditional approaches that call for students to learn, and recall information apart from its context, materials designed according to cognitive flexibility theory (in CBL, PBL or SBT) have been shown to promote transfer of complex knowledge to new settings (Jacobson & Spiro, 1993). Although these characteristics of CFT make it attractive we must consider that not all students are ready to accurately perform the type of tasks developed in consonance with this theory. Jacobson & Spiro suggested that students have different belief systems – epistemic beliefs – “related to the acquisition and structure of knowledge” and that these beliefs (which may not be consciously held) can determine the “kind of cognitive resources the student accesses in performing problem-solving tasks” (Jacobson & Spiro, 1993). Students’ epistemic beliefs have been associated with such learning problems, as the failure to integrate new knowledge with prior knowledge, use of rigid criteria for monitoring reading comprehension, and poor performance on comprehension measures (Schommer, 1993). In terms of the influence of epistemic beliefs on the subjects’ ability to learn using materials (designed accordingly to CFT), it is expected that some learners would prefer instructional approaches that tend toward context simplification (rather than complexity) and that stress the memorization of pre-specified knowledge (Spiro, 1988). Learners holding such beliefs, which the author refers to “as simple epistemic beliefs and preferences (simple EBP)”, are expected to be less able to learn with the nonlinear and multidimensional environments regarding problem-solving. In contrast, the author expected that, learners with more complex epistemic beliefs (complex EBP) prefer working with complex knowledge in multiple ways and value more active learner construction of knowledge, would be more successful at learning in problem-solving scenarios (Jacobson & Spiro, 1993). It has been suggested that maybe social constructivism techniques such as cooperative learning, might be one way to enhance the performance of students with simple EBP in a complex learning environment (Land, 1996)(Oliver, 1997).

Constructivism

Constructivism, as a philosophy of learning, sees itself as a process of constructing knowledge based on individual interpretation of experiences, considering prior knowledge, mental structures and framework of existing values (Jonassen, Mayes, & McAleese, 1993). In a constructivist perspective, knowledge instead of just being passed to the student, it must be built by himself. In this way, constructivism involves the adoption of strategies and activities appropriate to the, motivations, initial conceptions and knowledge of the student. Moreover, constructivism supports the integration of evaluation in the process of constructing meaning, and thus, tries to

ensure an informed and reflective learning over the quality of the results (Wenger, 1999). Constructivism substantiates authentic learning tasks, encouraging student ownership in the learning process, and suggesting that students should be given experience at knowledge construction, in order they can appreciate how to learn (Oliver, 1997). These principles are also reflected in the CFT, however the latter falls short to constructivism in the absence of provision of social context and collaboration (Jacobson, 1994). For CFT to become more closely matched with social constructivism ideals, it is necessary to combine them in a sort of “theoretical pluralism”; one in which new ways of assembling and applying knowledge from different perspectives are provided with associated justifications with evidence drawn from the facts of the case(s) (R. J. Spiro, Collins, Thota, & Feltovich, 2003). Knowledge understanding and application requires a constructivist approach (Spiro, 1988): this includes the ability to represent knowledge from different conceptual and case perspectives, and then, the ability to build from those multiple representations, a knowledge set, adapted to the needs of the situation at hand. Nowadays the application of these two educational approaches in the teaching of medicine (Coulson et al., 1997), nursing (Loar, 2007) or other biomedical sciences (Patel, Yoskowitz, Arocha, & Shortliffe, 2009), is growing.

Objectives

This paper aims to review the use and application of CBL, PBL and SBT in biomedical education (Medicine, Pharmacy; Nursing and Allied Health), as well as to document significant differences found in studies trying to assess effectiveness of the CBL, PBL and SBT as learning strategies. Research questions were identified as follows:

1. In what biomedical area is the use of CBL, PBL or SBT more common?
2. What are the students' perspectives regarding CBL, PBL or SBT?
3. Is there evidence of effectiveness of CBL, PBL or SBT approach, when compared to traditional teaching methods?
4. Is there evidence of effectiveness of CBL, PBL or SBT approach, when compared?

Methods

Well-defined literature search strategies are critical for enhancing the accuracy of any type of review because incomplete and biased searches result in an inadequate database and the potential for inaccurate results (Cooper, 1998). Ideally, all the relevant literature on the problem or topic of interest is included in the review; yet obtaining this literature can be challenging and costly (Jadad,

Moher, & Klassen, 1998). Our literature search consisted mainly on electronic search of published articles and congress proceedings in international educational databases and university repositories.

Study identification

A systematic search of published journal articles and conference proceedings, between 1990 and 2011, relating education based on problems in Biomedical Higher Education was made in the ERIC; EBSCO Academic Search Complete, MEDLINE, PubMed, JSTOR, CINAHL, Science Citation Index Expanded, Social Sciences Citation Index and Conference Proceedings Citation Index. Key Words used in the search consisted in : “Case Studies“, “Case Based Learning”, “CBL”, “PBL”, “Problem Based Learning”, “Simulation”, ” Simulation Based Training”, ” SBT”, “Student-Centered Learning”, “Active Learning”, “Health Education”.

Study selection

The titles, abstracts, and key words for each of these articles were reviewed by two members of the research team to assess their relevance regarding the research questions. The references of the selected articles were also surveyed for appropriate articles by a third member of the team. Criteria for selection included: (1) Description of the implementation of CBL; PBL or SBT in Biomedical Education; (2) Assessment CBL; PBL or SBT in Biomedical Education; (3) Comparative analysis of CBL; PBL or SBT in Biomedical Education. After considering all criteria for inclusion, we selected a total of 28 articles.

Data Treatment and Presentation

Data analysis in this review required that the data from primary sources was ordered, coded, categorized, and summarized into a unified and integrated conclusion about the research problem. Data analysis comprised of data coding from primary sources to simplify, abstract, focus, and organize data into a manageable framework (Whittemore & Knafl, 2005). Relevant data were extracted from all primary data sources and compiled into a matrix – see table 1. This approach provides simple and systematic organization of the main aspects of the different studies reviewed which simplifies the ability to compare primary sources on specific issues, variables, or sample characteristics.

Data Analysis and Discussion

The main areas where CBL, PBL or SBT are documented are the Medical field (12 registries), followed by Pharmacy (7), Nursing (4) and Allied Health (3). Proportionally speaking, 41% of articles found, discuss PBL methodology, 37% focus on CBL and only 15% on SBT. Only 4% of the studies approach the comparison CBL/ PBL and 3% PBL/SBT. Geographically, most studies

are from the USA (60%), and when referring to the study type, 25 % were instructional designs and assessments.

Case Based Learning Research Studies

The implementation and assessment of CBL is well documented in various levels of biomedical sciences such as Medicine, (Srinivasan et al., 2007), (Jamkar et al., 2008), Geriatrics (Struck & Teasdale, 2008), Nursing (Yoo et al., 2010), Therapeutics and Medicinal Chemistry (Ives et al., 1998),Pharmaceutics (R. Romero et al., 2004), Obstetrics and Gynecology (Massonetto et al., 2004), Anatomy (Peplow, 1990), Orthodontics (Engel & Hendricson, 1994) and Allied Health (McKay & White, 2003).

In all the latter mentioned examples, the clinical cases presented three essential elements summarized by Merrill (2003):

1. They are real or based on real-life situations;
2. They require the learner to carefully study and research, to understand the scenario.
3. They encourage the user to develop multiple perspectives based on material from the case.

We found several differences in the studies analyzed namely about, characteristics, the time of distribution to the students, and the number of students involved however, in all situations, the student had previous contact with text materials or even lectures. Class activities were structured around active and collaborative learning principles, and in all cases, except one (Ives et al., 1998), the class size was diminished compared to traditional lecture classes. The cases are generally discussed in groups ranging from 6-10 members depending on global class sizes. All case study classes are facilitated by a tutor, normally a faculty member. In some cases (Jesus et al., 2011) there are specific criteria for the selection of the tutor, based on professional activity or pedagogical training. Each group is then interviewed by the tutor at the end of the case study session. Normally the entire class is present for the interview, but individual questions are directed to one student at a time, with some extra questions, posed for anyone in the group to answer. The interview period lasts, on an average 5 -10 minutes for each group, and normally each student is asked to answer questions on a specific area/topic of the case study. To encourage a wider understanding of the case study, the questioning of each student can be broadened as the student shows the ability to answer more complex questions (Romero et al., 2004). There is also a possibility for other groups to intervene if requested.

Regarding the effectiveness of the CBL as a learning vehicle, most studies are unanimous when affirming it. According to Yoo et al (2010), significant group differences were observed in clinical decision-making and learning motivation, and post-test scores of clinical decision-making in the CBL group were statistically higher than the control group. Also Jamkar et al (2008) report that in the CBL group students scored better in short answer question and extended matching question

assessment, (p value 0.01). Romero et al (2004) in their mix CBL/PBL experiment also report a good relationship between student learning and case study performance (measured by grades for written case study reports and examination scores).

Concerning, students' perspectives about the CBL driven approach, the findings are also agreeable. (Massonetto et al., 2004) reports that students gave higher ratings to the CBL approach (p 0,05). Also Struck & Teasdale (2008) and Engel & Hendricson (1994) show that students rated the CBL approach positively, mainly due to the interactive nature of sessions and longitudinal nature of the cases. On this matter, the study conducted by Ives et al.(1998) thoroughly addresses students, who indicate that CBL improves understanding and application of clinical concepts.

We only came across with one study comparing CBL to PBL (Srinivasan et al., 2007). In this study, the authors tried to compare, faculty and medical students' perceptions of traditional PBL with CBL after a curricular shift at two institutions. Over periods of three years, the medical schools at the University of California, Los Angeles (UCLA) and the University of California, Davis (UCD) changed first, second, and third-year Doctoring courses from PBL to CBL formats. Ten months after the shift (2001 at UCLA and 2004 at UCD), students and faculty who had participated in both curricula completed a 24-item questionnaire about their PBL and CBL perceptions and the perceived advantages of each format. A total of 286 students (86%-97%) and 31 faculty (92%; 100%) completed questionnaires. CBL was preferred by students (255; 89%) and faculty (26; 84%) across schools and learner levels. From logistic regression, students preferred CBL because of fewer unfocused tangents (59%, odds ration [OR] 4.10, P = .01), less busy-work (80%, OR 3.97, P = .01), and more opportunities for clinical skills application (52%, OR 25.6, P = .002).

Problem Based Learning Research Studies

After the impact of McMaster University, innovative techniques were massively divulged, several medical and allied health science programs made changes to their curricula in order to join one or more aspects of PBL (McLoda, 2003). Nowadays the PBL approach is quite popular in Basic Medical Sciences (Wun et al., 2007), Ophthalmology (Sivam et al., 1995), Public Health (Gurpinar et al., 2005), Respiratory Therapy (Op't Holt, 2005), Nursing (Barrow et al., 2002; Rideout et al., 2002) and Laboratory Medicine (Beadling & Vossler, 2001). In the Pharmacy related subjects, studies have been conducted in Pharmacology (Sivam et al., 1995); Therapeutics (Benedict, 2010); Pharmaceutics (Romero et al., 2010) and Medicinal Chemistry (Webster & Riggs, 2006). Unlike the CBL approach, in PBL the case is not confined to one session. Normally, the information is presented to the students in vague details (ill-structured problem) and they are responsible for generating hypotheses, analyze data and propose a future inquiry. The PBL sessions can stretch for time periods equal or greater than one week, and post-session work varies according to the group's interests in pursuing

additional issues. A substantial number of articles discuss the implementation of PBL methods into the curriculum, alongside with the necessary measures that were taken to carry out this complex method. For example Winslade (1994) described the revision of a traditional therapeutics course to one that was based on the principles of pharmaceutical care and PBL. During the first class, students received detailed information about the PBL curriculum and the responsibilities of the students were emphasized. The next several classes focused on the development of the therapeutics. Once the process had been developed, the first case based problem was assigned. The author describes some challenges of the implementation of PBL, which included student evaluation and faculty training.

Other research articles have begun to assess the effects of PBL on students' academic performance and achievement. (Wun et al., 2007), compared students of PBL and non-PBL curricula in students' talking time and participation in small-group tutorials in a medical school in Asia. PBL students scored significantly higher than non-PBL students in all items (except one item - respect to peers) of the tutorial assessment scales, and in the mean scores of both the group interaction scale and active participation scale. The results suggested that PBL starting from the early years of a medical curriculum was associated with more active student participation, interaction and collaboration in small-group tutorials. Gurpinar et al (2005) planned a cross-sectional study including the fifth and sixth year medical students of Dokuz Eylul University in Turkey. The fifth year students (PBL group, n=56) were the first educated according to a PBL curriculum since the 1997-1998 academic year. The sixth year students (traditional education group, n=78) were the last students educated with traditional educational methods. They prepared 25 multiple-choice questions to assess knowledge scores of students on selected subjects of Public Health. Mean test scores achieved in PBL and traditional groups were 65.0 and 60.5 respectively. PBL students were significantly more successful in the knowledge test ($p = 0.01$). The knowledge scores of two topics (health management and chronic diseases) were statistically higher among PBL students. On a different level, Kong et al (2009), randomly divided ninety students into 3 classes. The first class studied under a didactic model. The other 2 classes were divided into 6 groups and received PBL teaching; 3 groups studied via cases presented in digital form and the others studied via paper-form cases. The results of theoretical and case analysis examinations were analyzed using the chi-squared test. Student performance on the interval practice was analyzed using the Kruskal-Wallis test. Questionnaires were used to evaluate student and facilitator perceptions. Students in the digital groups exhibited better performance in the practice procedures according to tutorial evaluations compared with the other groups ($P < .05$). The 2 PBL classes had significantly higher mean results of theoretical and case analysis examinations ($P < .001$), but there was no significant difference between

the 2 PBL classes. With very different results Webster & Riggs (2006) established a PBL format for the medicinal chemistry course and assessed the outcomes of student learning. Pre-course and post-course examinations were given to students enrolled, and appropriate statistical analyses were conducted. Although both cohorts demonstrated an increase in raw score for the pre to the post examination, somewhat surprising was the statistical difference observed in comparing the non-PBL cohort post-test results versus the PBL cohort post-test results, where the PBL cohort appeared to learn less of the course content. The authors justify this difference in stating that the more time is required to cover content in a PBL course than when traditional course delivery methods are used. These differences in results across the several studies, point out the necessity for more assessments to better understand how, when, and if PBL fosters the development of certain types of learning outcomes (Jones, 2002).

Simulation Based Training Research Studies

The introduction of SBT, or patient simulation into health education programs, has spread from anesthesiology (Gaba, 1992), emergency medicine (Bond & Spillane, 2002), vascular surgery (J. T. Lee et al., 2009), pediatrics (Fiedor, 2004), neonatology (Campbell et al., 2009), radiology (Desser, 2007), and pharmacy (Seybert & Barton, 2007). Steadman et al. (2006) and other proponents (Morgan, Cleave-Hogg, McIlroy, & Devitt, 2002), argue that SBT benefits include standardization and repetition of content, interactive learning in clinical setting, without patient risk, and the ability to design a goal-oriented clinical experience. There are some similarities regarding SBT and PBL, as in both the evolution of the scenario is dynamic, and there is a relevant feedback elicited from the learner. Nevertheless, in PBL there is no mannequin, no medical equipment or other medical staff present. Differences continue, when one realizes that in SBT, there is no verbal feedback from the tutor, but responses to interventions are displayed on a monitor or similar equipment. The use of human simulators to reproduce life-threatening situations can be especially useful in assessing the clinical competence of emergency medicine (Bond & Spillane, 2002), but can also be applied to a broader set of health practices. Seybert & Barton (2007), in their recent work, aimed to assess the effect of SBT on PharmD students' ability to perform accurate blood pressure assessments and to measure student satisfaction with this novel teaching method. Didactic lectures on blood pressure assessment were combined with practical sessions using a high-fidelity computerized patient simulator. Before and after the simulation sessions, students (n=95) completed a written objective examination to assess knowledge and completed a survey to determine their attitudes regarding the learning experience. Individual clinical skills were assessed using the patient simulator. Significant improvement was seen in students' knowledge and their ability to accurately determine blood pressure following SBT sessions. Survey responses indicated that students felt confident that SBT

would improve their ability to perform accurate blood pressure assessments. On a different record, Lee et al (2009) designed a prospective observational cohort study of medical student performance to assess the ability of SBT in the improvement the technical performance and interest level in vascular surgery. Students (n=43) completed a survey of their interests and performed a pretest which consisted in a renal stent procedure on an endovascular simulator. The curriculum consisted of didactic teaching and weekly mentored simulator sessions and concluded with a final renal stent procedure on the simulator (post-test). Objective procedural measures were determined during the pre- and post-test by the simulator, and subjective performance was graded by expert observers using a structured global assessment scale. The objective and subjective criteria measured on the simulator and structured global assessment scale significantly improved from pre- to post-test in terms of performer technical skill, patient safety measures, and structured global assessments. An analysis of the entire cohort revealed a mean total score on the structured global assessment scale to be 1.82 on the pre-test, which improved to 3.93 (out of a maximum score of 5.0). With different results Campbell et al (2009), randomly assigned 15 first-year residents to demonstrate neonatal resuscitation knowledge, with either the hi-fi mannequin or a traditional plastic mannequin. A written evaluation was conducted before and after the intervention. Each pair of residents experienced the two scenarios. Video performance was then assessed and compared. Residents randomly assigned to the hi-fi mannequin rated the experience higher and required less redirection from instructors during the procedure however they did not have improved written scores or intubation times. We only came across one study comparing SBT to PBL. Steadman et al (2006) proposed to find whether SBT is superior to interactive PBL for teaching medical students acute care assessment and management skills. Eligible students were randomized to either the SBT or PBL group. On day 1, all subjects underwent a simulator-based initial assessment designed to evaluate their critical care skills. Two blinded investigators assessed each student using a standardized checklist. Subsequently, the PBL group learned about dyspnea in a standard PBL format. The SBT group learned about dyspnea using the simulator. To equalize simulator education time, the PBL group learned about acute abdominal pain on the simulator, whereas the SBT group used the PBL format. On day 5, each student was tested on a unique dyspnea scenario. Mean initial assessment and final assessment checklist scores and their change for the SBT and PBL groups were compared using the Student's t-test. The SBT and PBL groups had similar mean (PBL 0.44, SBT 0.47, $p=.64$) initial assessment scores and were deemed equivalent, however the SBT group performed better than the PBL group on the final assessment (mean, PBL 0.53, SBT 0.72, $p <.0001$).

Methodological limitations of studies

The assessment of the extent of the problem depends largely on the variability of definitions of CBL, PBL and SBT, the instruments used, the area of studies, the level of education, the maturity of the students, the geographical area or the resource to Information and Communication Technologies (ICT) during classes. The terms Case Based Learning; Problem Based Learning and Simulation Based Training may have many different meanings depending on the design of the educational method employed and the skills of the teacher. The many variables possible can produce wide variations in quality and in the educational objectives that can be achieved. A taxonomy was already proposed by Barrows (1986) to ease an awareness of these differences and to help teachers choose a learning method most appropriate for their students. Nevertheless, each educator has its own set of views and experiences, which may influence the design of educational method. Moreover, the different disciplines in each biomedical area represent unique realities that may require an adaptation to the initial taxonomy proposed by Barrows (1986). This multitude of variations enriches the educational field in Biomedical Sciences, however it can also interfere in a correct and vast transversal analysis of results. In addition, level of education (grad/ post-grad) and student maturity (age), play a crucial role in the learning outcomes, and again could not be controlled during the review. It is notable the variety of geographical locations related to the studies retrieved. Despite the fact that any health professional should have an equivalent education, to have a good performance during professional practice, one must not discard the possibility that different locations and academic cultures may exist and can contribute (positively or not) in the outcomes of learning during a CBL, PBL or SBT model. Finally, the resort to ICT during the CBL, PBL or SBT sessions has been known to have a potential role in the learning outcomes and students' perspectives. Since not all retrieved studies, resorted to ICT, this consists of another variable that can also interfere in a correct and vast transversal analysis of results.

Major findings and final remarks

Our research indicates that the use of CBL, PBL and SBT is well documented in Biomedical Education, being Medicine is the most common area to be associated with these approaches. This result may be explained by the large amount of literature being published, the large number of medical faculties, and because other biomedical areas, like Allied Health and Pharmacy, represent a younger existence when compared with traditional Medical education. When addressing the effectiveness of CBL, PBL and SBT as learning vehicles, evidences has been given in all latter when compared to traditional didactic teaching, however, there is still little work published that focus on the comparison of CBL, PBL and SBT with one another. Although the situations present are, in general, success cases, one must constraint in making generalized affirmations regarding significant

difference in student learning and development, mainly because longitudinal studies are scarce. Students' perspectives and attitudes towards these learning approaches are, in general positive. However we must also take into account that the “novelty effect” might be present which reinforces the idea that studies conducted through large periods of time are necessary to infer safely on this topic.

Although conversion of traditional, independent courses to active-learning approaches have been challenging, faculty and students generally view the integration of CBL/PBL/STB in the teaching of biomedical professions as positive and rewarding in terms of improving student participation, performance and motivation. Despite the fact CBL/PBL/STB demands more learning time to cover the same contents, the CBL/PBL/STB approaches lead students to work together, retain key concepts and to apply them to patient care situations. Students generally respond positively to these approaches and realize their importance to the future professional life. Continued efforts are still needed to, more thoroughly determine, the effectiveness of each approach in improving student learning and knowledge retention.

Indeed, CBL, PBL and STB have a powerful place in instruction and the classroom, but caution is warranted regarding the strategies used. Instead of beginning instructional planning with these methods in mind, the learning objectives and instructional strategies should guide the adoption process. An awareness of the different methods gives faculty members additional mechanisms from which to choose, but selecting an appropriate instructional strategy is even more important.

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Anexs - summarizes the characteristics of the studies, focusing on, study design, purpose, implementation year and duration, country, biomedical area, participants, learning approach and main conclusions.

Studies	Type of Publication	Study Design	Purpose	Implementation Year; Duration	Country	Biomedical Area	Participants	Learning Approach	Main Conclusions
(Peplow, 1990)	Journal Article	Instructional Design ; Survey	Development of self-directed learning skills in second-year medical students by introducing case-based projects in the gross anatomy course at a long-established medical school.	1990	New Zeland	Medicine	Information unavailable	CBL	Students recognize that the projects were about obtaining a deeper understanding of the anatomy, and the programs appear to have promoted the use and study of library texts
(Engel & Hendricson, 1994)	Journal Article	Instructional design and assessment	Implementation and assessment of CBL in Orthodontics for Dental Medicine	1994	USA	Dental Medicine	93 students	CBL	Both students and instructors rated the seminars positively. Students reported significantly higher levels of confidence after the seminars for each of seven reasoning skills. This teaching method can be applied to other dental areas to better develop the clinical reasoning skills of future dentists
(Sivam, Iatridis, & Vaughn, 1995)	Journal Article	Cross-sectional study?	Design, implementation and assessment of PBL in Pharmacology	1994? ; 2 years	USA	Medicine	16 students	PBL	Suggests that the segmental integration approach of instruction coupled with a system of content (internal and external examinations) and process (tutorial and triple-jump) evaluations, as outlined in this paper is a contextualized learning method that offers an effective way of imparting pharmacology knowledge to medical students
(Ives, Deloatch, & Ishaq, 1998)	Journal Article	Instructional design and assessment	Development, implementation, and evaluation of a student-centered, case-based, integrated sequence of core courses in medicinal chemistry and pharmacotherapy	1994-1998	USA	Pharmacy	100	CBL	Case-based learning increased the amount of time spent in class preparation/self-directed learning and improved student's ability to grasp and apply concepts

Table 1 - studies published between 1990 and 1998.

Studies	Type of Publication	Study Design	Purpose	Implementation Year; Duration	Country	Biomedical Area	Participants	Learning Approach	Main Conclusions
(Beadling & Vossler, 2001)	Journal Article	Instructional design and assessment	Implementation of PBL in BSc curriculum in medical technology	2001	USA	Allied Health	Not applicable	PBL	Increased ability of students to evaluate information from multiple perspectives and to integrate content from across the laboratory disciplines to analyze and solve problems in their clinical rotations and didactic course work. From a motivational standpoint, the overall reaction of students to this learning format has been very positive.
(Barrow, Lyte, & Butterworth, 2002)	Journal Article	Multiple methods of observation, focus group interviews and a questionnaire	Evaluated the reiterative PBL approach in an undergraduate program within one University	1999	UK	Nursing	33	PBL	Findings revealed an overall positive student experience of PBL. Many students found PBL initially stressful due to the deliberately ambiguous nature of the scenario and the requirement upon students to direct their own learning
(Rideout et al., 2002)	Journal Article	Cross-sectional analytical design	Compare graduating students in a problem based curriculum with those in a conventional nursing program with regard to perceived preparation for clinical practice, clinical functioning, knowledge and satisfaction with their education.	1999	Canada	Nursing	PBL Group :42 Non PBL :31	PBL	Overall, our results indicate that the perceived confidence of the PBL students in their knowledge for clinical practice was greater than that of their counterparts educated within a conventional curriculum. This is supported by their similar pass rates on the RN examinations.
(Bond & Spillane, 2002)	Journal Article	Instructional design and assessment	Use of Simulation for Emergency Medicine Resident Assessment	2002	USA	Medicine	Information unavailable	SBT	Simulations are exercises designed to mimic real-life situations in which learners are given the opportunity to reason through a clinical problem and make critical decisions without the potential of harming actual patients

Table 2 - studies published between 2001 and 2002.

Studies	Type of Publication	Study Design	Purpose	Implementation Year; Duration	Country	Biomedical Area	Participants	Learning Approach	Main Conclusions
(McKay & White, 2003)	Journal Article	Action Research	Reviews the progress of the two final year subjects as well as the implementation of the same learning strategy in a second year subject.	2000-2002	Hong Kong	Allied Health	1st year : 46 2nd year: 49	CBL	Students increased independence in learning, their understanding and integration of learning in the applied context, and their willingness to be party to a more open learning situation that encourages them to assume greater personal responsibility.
(R. Romero, Erikson, & Haworth, 2004)	Journal Article	Instructional design and assessment	Document the experience with this teaching approach and describes the evolution of the course.	1993-2003	USA	Pharmacy	1781	PBL	A case study-driven PBL course with a large class size can be effective in enhancing student learning across a range of abilities, and verbal assessment by faculty and student peer review can play useful roles in this process.
(Massonetto, Marcellini, Assis, & de Toledo, 2004)	Journal Article	Survey	Evaluate the impact of the introduction of case discussions and other practical activities upon students' perceptions of the learning process	2002/2003	Brazil	Medicine	2002 (Group I; 108 students) 2003 (Group II; 113 students).	CBL	Students were very receptive to the new teaching model
(Gurpinar, Musal, Aksakoglu, & Ucku, 2005)	Journal Article	Cross-sectional study	Compare the knowledge scores of medical students in Problem-based Learning and traditional curriculum of public health topics	2002	Turkey	Medicine	78 students (non-PBL) 56 students (PBL)	PBL	Mean total evaluation score in the PBL group was 4.5 points higher than in the traditional group in our study.
(Op't Holt, 2005)	Journal Article	Instructional design and assessment	Implementation and assesement of PBL in respiratory Care for Allied Health	2005	USA	Allied Health	Not applicable	PBL	Students enjoy the process and think that they are performing clinically better than their non-PBL peers. Pass rates for the Clinical Simulation examination are above the national average.

Table 3 - studies published between 2003 and 2005.

Studies	Type of Publication	Study Design	Purpose	Implementation Year; Duration	Country	Biomedical Area	Participants	Learning Approach	Main Conclusions
(Webster & Riggs, 2006)	Journal Article	Pre- post-test with non equivalent control group	Establish an aggressive problem-based learning (PBL) format of the medicinal chemistry course and assess the outcomes of student learning.	2005	USA	Pharmacy	98 students (PBL) 100 students (non-PBL)	PBL	Problem-based learning may not be the ideal method for teaching medicinal chemistry. This may be due to several factors including: student learning type, the lack of a cognitive framework for learning in the basic sciences, and time constraints
(Steadman et al., 2006)	Journal Article	Randomized Controlled Trial	To determine whether a full-scale simulation is superior to interactive PBL for teaching medical students acute care assessment and management skills	2006; one week	USA	Medicine	31, fourth-year medical students	SBT vs PBL	For fourth-year medical students, simulation-based learning was superior to problem-based learning for the acquisition of critical assessment and management skills.
(Wun, Tse, Lam, & Lam, 2007)	Journal Article	Cross-sectional study with a historical-control group	This study compared students of PBL and non-PBL curricula in students' talking time and participation in small-group tutorials in a medical school in Asia	1995 and 2002	China	Medicine	44 students in 1995 and 42 students in 2002	PBL	The results suggested that PBL starting from the early years of a medical curriculum was associated with more active student participation, interaction and collaboration in small-group tutorials
(Srinivasan, Wilkes, Stevenson, Nguyen, & Slavin, 2007)	Journal Article	Survey	Comparison of faculty and medical students' perceptions of traditional PBL with CBL after a curricular shift at two institutions	2001 at UCLA and 2004 at UCD; 3 years duration.	USA	Medicine	286 students and 31 faculty members	CBL vs PBL	CBL was preferred by students and faculty.
(Seybert & Barton, 2007)	Journal Article	Within Subjects Design	To assess the effect of simulation-based learning on doctor of pharmacy students' ability to perform accurate blood pressure assessments and to measure student satisfaction with this novel teaching method.	2007	USA	Pharmacy	90	SBT	Significant improvement was seen in students' knowledge and their ability to accurately determine blood pressure following simulation sessions

Table 4 - studies published between 2006 and 2007.

Studies	Type of Publication	Study Design	Purpose	Implementation Year; Duration	Country	Biomedical Area	Participants	Learning Approach	Main Conclusions
(Loar, 2007)	PhD Thesis	Experimental Design with alternative treatment groups	Assess the impact of a computer simulated case study on nurse practitioner students' declarative knowledge and clinical performance	2007	USA	Nursing	Information unavailable	CBL	The results of this study revealed that there was no difference in either declarative knowledge or The clinical performance between those students who completed a text based case study and those students who completed a computer simulated case study.
(Struck & Teasdale, 2008)	Journal Article	Instructional design and assessment	Describe the CBL experience, report student satisfaction with the CBL process, and discuss how students value CBL as a teaching method compared to other methods.	2003	USA	Medicine	Information unavailable	CBL	The results indicate that CBL is highly valued among the students due to the interactive nature of the sessions and longitudinal nature of the cases.
(Jamkar et al., 2008)	Journal Article	Quasi-experimental?	The hypothesis was to see whether the proposed CBL model would work in Indian set up in comparison with traditional teaching	2008	India	Medicine	57 (study group) 56 (control group)	CBL	Although size of the sample is small, CBL is found to be an effective modality of imparting medical education with effective integration of all departments.
(Kong, Li, Wang, Sun, & Zhang, 2009)	Journal Article	Post-test with non-equivalent control group	To assess the impact of digital problem-based learning (PBL) cases on student learning in ophthalmology courses	2007	China	Medicine	30 randomly divided students per class) Digital PBL; Paper PBL; Didactic Model	PBL	Students in the digital groups exhibited better performance in the practice procedures according to tutorial evaluations compared with the other groups. The 2 PBL classes had significantly higher mean results of theoretical and case analysis examinations, but there was no significant difference between the 2 PBL classes.
(Lee et al., 2009)	Journal Article	Prospective observational cohort study	The purpose of this study is to assess the ability of a simulation-based curriculum to improve the technical performance and interest level of medical students in vascular surgery.	2007/2008; 8 weeks	USA	Medicine	41 Students	SBT	The use of high fidelity endovascular simulation within an introductory vascular surgery course improves medical student performance with respect to technical skill, patient safety parameters, and global performance assessment.

Table 5 - studies published between 2007 and 2009.

Studies	Type of Publication	Study Design	Purpose	Implementation Year; Duration	Country	Biomedical Area	Participants	Learning Approach	Main Conclusions
(Campbell, Barozzino, Farrugia, & Sgro, 2009)	Journal Article	Pilot study	Use of a hi-fi simulation mannequin was compared with a standard plastic mannequin	2009	Canada	Medicine	15	SBT	Demonstrated that a hi-fi mannequin can be used as part of an educational program, such as the NRP. The use of this technology in neonatal resuscitation training is well-received by learners and may provide a more realistic model for training.
(R. M. Romero, Eriksen, & I. S. Haworth, 2010)	Journal Article	Counter balanced measures design	To assess the effectiveness of assisted g PBL compared to a didactic approach in a pharmaceuticals course.	2002-2008	USA	Pharmacy	1320	PBL	PBL produced a short-term (weeks) improvement in learning and our results suggest that the effect may persist in the medium term (months).
(Benedict, 2010)	Journal Article	Instructional design and assessment	To enhance student learning of a complex therapeutic concept through the incorporation of 2 case-based, active-learning strategies with lecture in a required advanced therapeutics course.	2009; one semester	USA	Pharmacy	107	PBL	Based on student learning assessments and course survey evaluations, the course was not only well received by students, but also fostered an effective learning environment.
(Yoo, Park, & Lee, 2010)	Journal Article	Nonequivalent control group; Non-synchronized design	Examine the effects of case-based learning (CBL) using video on clinical decision-making and learning motivation.	2009-2010	Korea	Nursing	44 nursing students divided in two groups	CBL	Results indicate that CBL using video is effective in enhancing clinical decision-making and motivating students to learn by encouraging self-directed learning and creating more interest and curiosity in learning
(Jesus et al., 2011)	Conference Proceedings	Instructional design and assessment	Implementation of case-based, learner-centered approach to Pharmacotherapy	2009-2010	Portugal	Pharmacy	86	CBL	Faculty and students generally view the integration of CBL in the teaching of pharmacotherapy as positive and rewarding in terms of improving student participation, performance and motivation.

Table 6 - studies published between 2009 and 2011.