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How does medical education affect empathy and compassion in medical students? A meta-ethnography: BEME Guide No. 57

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ABSTRACT

Background: Empathy and compassion are important in healthcare delivery, and are necessary qualities in medical students.

Aims: To explore medical students', patients' and educators' perceptions of what affects empathy and the expression of compassion; and to address gaps in knowledge, attitudes and skills on how education affects empathy and the expression of compassion in medical students.

Methods: The seven steps by Noblit and Hare were used for this meta-ethnography. Databases were searched for studies in English, published from 2007 to 2017 with outcomes of empathy and compassion. Key themes and concepts were identified, and accounts from the studies were used to build interpretations.

Findings: Thirty-three qualitative studies were included and four main themes were derived: seeing the patient as a person; appreciating the elements of empathy and compassion; navigating in the training environment; and being guided by ideals. Interactions between the patient, the medical student and training environment which affect the development of empathy and compassion are illustrated in a conceptual model.

Conclusions: This meta-ethnography extends our understanding of how medical education affects the expression of empathy and compassion in medical students. The results provide important considerations for medical educators and faculty developers in further developing and improving medical curricula.

Introduction

Empathy is important to help doctors explore and understand patients' needs and experiences, and to provide good quality patient care (Eikeland et al. 2014). Empathy enables a clinician to carry out core medical tasks more accurately and is regarded as a key determinant of quality in medical care (Neumann et al. 2009). Compassion is a concept frequently associated with empathy, and there is an increasing emphasis on the need for compassion in healthcare delivery (Schantz 2007). Below we consider the concepts of empathy and compassion first separately, then how they are related, and their importance for medical education.

The benefits of empathy in doctors have been reported in a systematic review conducted in general practice, in which empathy was found to be associated with improved patient satisfaction, better diagnostic and clinical outcomes, and enhanced patient enablement (Derksen et al. 2013). However, as a concept, there is no consensus definition of empathy (Pedersen 2009). Coulehan et al. (2001) considers empathy in the clinical setting to have three implications, namely a "cognitive focus," an "affective or emotional focus" and an "action component" (p. 221); while Mercer and Reynolds (2002) consider empathy to be a process, involving the ability to understand the patient's situation, perspective and feelings, to communicate back that understanding, and to act on that understanding in a helpful and therapeutic way. This definition by Mercer and Reynolds (2002) is one of the most frequently used definitions of physician empathy (Neumann et al. 2011).

Practice points

- The expression of empathy and compassion arises from the unique interaction between a medical student and a care recipient.
- Approaches like creative writing and films are complementary to, and not a substitute for, other more patient-focused opportunities.
- Students should have opportunities to observe desirable behaviors of empathy and compassion in authentic learning contexts, and to share their views in a reflective space with open dialogue.
- Educators should consider learners' professional priorities, emphasize the interpersonal nature of empathy, and encourage students to be genuinely interested in patients.

Several systematic reviews have investigated the development of empathy among medical students and residents; and questions have been raised regarding the usefulness of validated, self-reported questionnaires in predicting perceived empathy in practice, and the failure to consider interactional efforts between patient, doctor, clinical and institutional contexts (Batt-Rawden et al. 2013; Fernando et al. 2016; Sulzer et al. 2016). Differing findings

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Supplemental data for this article can be accessed here.

from reviews have been reported with some reviews showing that empathy appeared to decline during medical school and residency (Pedersen 2010; Neumann et al. 2011) while others reported little or no change in empathy scores (Colliver et al. 2010; Ferreira-Valente et al. 2017). The empathy instruments used in these studies were not validated with real or standardized patients' perceptions of empathy in actual or simulated clinical encounters (Colliver et al. 2010); and many of the studies failed to provide a clear definition of empathy (Sulzer et al. 2016). Additionally, many studies were found to have contradictions in the way empathy was conceptualized and operationalized (Sulzer et al. 2016).

Numerous educational interventions including patient narratives and creative arts, writing, drama workshops, communication skills training, and experiential learning, have been developed to encourage the development of empathy, compassion and respect for patients in medical students (Wear and Zarconi 2008; Batt-Rawden et al. 2013). Reflective writing has also been found to improve students' levels of empathy, and has been recommended to be included in any medical curriculum (Chen and Forbes 2014). Despite efforts to promote the development of empathy and compassion through various interventions in the humanities, the influence of the hidden curriculum should not be neglected. Hafferty and Franks (1994) call for cognizance of the hidden curriculum which includes the structure of training, educators' views and conversations outside of the classroom setting. Additionally, both intentional and unplanned role modeling of doctors have been shown to have a substantial influence on the development of medical professionalism in learners (Passi et al. 2013). Batt-Rawden et al.'s (2013) review suggests that educational interventions can be useful in maintaining and enhancing empathy in undergraduate medical students however recommends that further studies be conducted on specific strategies and best practices to inform medical education.

In the medical education literature, empathy has been described in other ways including: dutifulness (Wolf 1980); prosocial behavior (Lockwood et al. 2014); moral reasoning (Olsen 1997); sympathy (Svenaeus 2015); and altruism (Persson and Kajonius 2016). Fernando et al. (2016) consider that compassion is "built on the capacity to empathize – a form of cognitive and emotional perspective taking – but involves the additional step of wanting to alleviate suffering" (p. 340). Similarly, as defined in Goetz et al.'s review (Goetz et al. 2010), compassion is "the feeling that arises in witnessing another's suffering and that motivates a subsequent desire to help" (p. 351).

Compassion is often considered a core competency and sign of quality care (Sinclair et al. 2016). Compassion also helps medical students overcome fear and develop deep and lasting empathy (Shapiro 2008). Empathy without compassion may cause distress when a clinician faces intense suffering, subsequently leading to emotional fatigue and burnout (Fernando et al. 2016). As stated in The Lancet (2007), "although compassion is often cited as one of the core values of professionalism, there remains a continuous and inconclusive debate about whether compassion is innate or can be taught." (p. 630). In other literature, there is also a call for compassion and humanism to be embedded and nurtured in health care, health professional schools and standards (Gaufberg and Hodges 2016); and for compassion to be integrated in collaborative care to improve health and experiences (Lown et al. 2016). It is thus important to promote the development of both empathy and compassion in clinicians for better patient care and to mitigate burnout in clinicians.

Sulzer et al. (2016) proposed that the relational aspects of empathy should be studied, rather than conceptualized solely as a personal attribute. Personal factors are also not the sole determinants of the emergence of compassion as it is also profoundly influenced by patient factors, system factors and clinical factors (Fernando et al. 2016). There is a lack of understanding of how the learning contexts including the structure of curricula affect the development of empathy and compassion in medical students (Ferreira-Valente et al. 2017). Existing qualitative studies exploring medical students' experiences of the different educational interventions provided insight to aspects and elements in medical curricula that students perceived as beneficial for developing empathy and compassion (Allen et al. 2008; Michalec 2011; Lutz et al. 2013; Eikeland et al. 2014; Batley et al. 2016). Studies that examined patients' perspectives (Kenyon and Brown 2007; Breytspraak et al. 2008) further enhanced our understanding of the influence of educational interventions on the expression of empathy and compassion by medical students since patients are the recipients of medical care. Hence, we proposed to review and synthesize the evidence on how medical education curricula affect empathy and compassion in medical students, and how this is perceived by medical students, educators and patients.

Aims

The aims of this review were to synthesize the evidence on how medical education affects empathy and compassion in medical students, and how this is perceived by medical students, educators and patients. The objectives were to:

- Examine medical students', educators' and patients' perceptions and experiences of what affects empathy and compassion in medical students.
- Build a new interpretive account from the primary empirical qualitative studies to understand how education affects empathy and compassion in medical students.
- Provide useful information and important consideration points for medical educators and faculty developers in developing medical curricula including clinical placements.

Methods

Qualitative studies offer in-depth understanding of nuanced relationships, authentic perspectives, and educational dilemmas (Bearman and Dawson 2013). There are several methods for synthesizing qualitative evidence, and a meta-ethnography can be used for synthesizing qualitative data, to provide interpretations by translating studies into one another (Britten and Pope 2012). A meta-ethnography method was chosen for this review because it

allowed us to synthesize qualitative studies that investigated perceptions and experiences of medical students, educators, and patients' on the aspects of the medical curriculum affecting empathy and compassion. Through the process of a meta-ethnography, the understanding and transfer of ideas, concepts, and metaphors across studies is encouraged (Britten and Pope 2012); and allows the synthesis to move toward reconceptualization, providing new insights on the research phenomenon (Britten et al. 2002; Doyle 2003).

This meta-ethnography was conducted according to our protocol published previously on the BEME website (Krishnasamy et al. 2016). We used the seven steps by Noblit and Hare (1988) namely: (1) Getting started: involves determining the focus of the data synthesis; (2) Deciding what is relevant to the initial interest: involves locating studies and making decisions on inclusion and quality assessment; (3) Reading the studies: involves reading the accounts and noting metaphors, concepts, or themes; (4) Determining how the studies are related: involves comparing concepts, metaphors and concepts from studies, and to see how they are similar or different; (5) Translating studies into one another: involves comparing concepts and metaphors between and within study accounts, to see how they relate to other key concepts or metaphors; (6) Synthesizing translations: involves making a whole from common types of translations or concepts and reaching new interpretations; and (7) Expressing the synthesis: involves conveying the findings of the synthesis.

Following the pilot scoping (Krishnasamy et al. 2016), we searched for articles using the search terms shown in Table 1. The purpose of the search was to identify and retrieve studies with qualitative research designs that discussed education for medical students with outcomes of empathy and compassion that are in English, and were published from 2007 to 2017 to capture articles on recent curricula and teaching methods. Study designs of interest included phenomenology, ethnography, grounded theory, narrative research, case study, and articles with qualitative data. Qualitative articles are suitable because they allow an understanding of study participants' perspectives and provide insight to their social situations and interactions (Creswell 2009). Hence, these articles would enable us to gain insight into how education affects empathy and the expression of compassion in medical students, and thus answer our research questions.

The search strategies and databases used for the literature search are shown in Table 2.

Table 1. Search terms used for database searching for the pilot scoping.

P	I	C	O
Medical undergraduate[a]		Qualitative	Empathy
Medical student[a]		Phenomenology	Compassion
Medical educat[a]		Ethnography	
Medical faculty		Grounded theory	
Medical teach[a]		Interview[a]	
		Narrative[a]	
		Focus group[a]	
		Meta-ethnography	
		Case study	
		Thematic analysis	
		Framework analysis	

[a]Truncations used during database searching.

A total of 1454 papers were identified through the database searching. These records were exported to EndNote 8. The results from each database are shown in Table 3.

Of these, 482 duplicates were removed, and the titles and abstracts of the remaining records were then screened independently by at least two reviewers in EndNote 8 using the study selection criteria in Table 4. We used the steps by Bramer et al. (2017) to guide us in using EndNote 8 for this process.

In total, 860 records were deemed unsuitable and excluded, and the full texts of the remaining 112 were retrieved. Each of these articles was then independently read by at least two reviewers to determine suitability for inclusion in the study. After the full text articles were read, 33 articles were deemed suitable for inclusion in the meta-ethnography. A summary of this process is shown in the adapted PRISMA flowchart (Moher et al. 2009), in Figure 1.

Each paper was randomly allocated to at least two reviewers. The data extraction form developed for the review and reported in the protocol was used to extract the information relevant to our review aims, and is available on the BEME website (Krishnasamy et al. 2016). The data extraction form was piloted with a few studies and revised by all review team members. Information extracted included details on country, type, format and design of educational interventions and programs, and educators. Supplemental Table 5 details information on the publication, study design, location and setting, and the objective of the study and type of teaching activity involved. Descriptions of the experiences, attitudes and perceptions of empathy and compassion were also extracted from the papers for data analysis.

At least two reviewers extracted the data from each paper, and appraised the quality of each of the 33 studies. Any disagreement was resolved through discussion with a third reviewer. All papers that did not address medical education and empathy or compassion were excluded. Data extraction and quality appraisal were documented and organized using Excel. The results of the quality appraisal based on CASP criteria (CASP 2014) are presented in the Appendix Supplementary Table 1.

Each paper was read by three members of the research team several times, and key concepts and ideas which are known as "metaphors" were extracted and documented (Noblit and Hare 1988). NVivo Software (NVivo Qualitative Data Analysis Software 2014) was used in the process of coding the findings from the data. Descriptions of students', patients', family members', and educators' experiences of empathy and compassion were also extracted verbatim from each paper and categorized into "First order constructs" (participants' own words extracted from the articles) and "Second order constructs" (researchers' interpretations extracted from the paper) (Cahill et al. 2018, p. 133). The papers were read across for common and recurring concepts (Britten et al. 2002). The reviewer team proposed concepts that were defined differently and implicit to the included studies. A list of all the ideas, metaphors, phrases and themes that were generated from each paper were juxtaposed to see how they occurred, recurred or were encompassed in each study, and relationships between and across studies were then explored, and concepts and themes across all studies were displayed in a

Table 2. Databases and search strategies used for the literature search.

Database	Search strategy
Cumulative Index to Nursing and Allied Health Literature (CINAHL)	[AB medical undergraduate* OR AB medical student* OR AB medical educat* OR AB medical faculty OR AB medical teach*] AND [AB empathy OR AB compassion] AND [AB qualitative OR AB phenomenology OR AB ethnography OR AB grounded theory OR AB interview* OR AB narrative* OR AB focus group* OR AB meta-ethnography OR AB case study OR AB thematic analysis OR AB framework analysis] Limiter: English
EMBASE	1. (Medical undergraduate* or Medical student* or Medical educat* or Medical faculty or Medical teach*).af. 2. (Qualitative or Phenomenology or Ethnography or Grounded theory or Interview* or Narrative* or Focus Group* or Meta-ethnography or Case study or Thematic analysis or Framework analysis).af. 3. (Empathy or Compassion).af. 4. 1 and 2 and 3 5. limit 4 to English language
Education Resources Information Centre (ERIC)	1. Medical undergraduate* OR Medical student* OR Medical educat* OR Medical faculty OR Medical teach* 2. Qualitative OR Phenomenology OR Ethnography OR Grounded theory OR Interview* OR Narrative* OR Focus Group* OR Meta-ethnography OR Case study OR Thematic analysis OR Framework synthesis 3. Empathy OR Compassion 4. 1 AND 2 AND 3 Limiter: English
PsycINFO	1. Medical undergraduate* OR Medical student* OR Medical educat* OR Medical faculty OR Medical teach* 2. Qualitative OR Phenomenology OR Ethnography OR Grounded theory OR Interview* OR Narrative* OR Focus Group* OR Meta-ethnography OR Case study OR Thematic analysis OR Framework synthesis 3. Empathy OR Compassion 4. 1 AND 2 AND 3 Limiter: English
PubMed	((((((((((qualitative) OR phenomenology) OR ethnography) OR grounded theory) OR interview*) OR narrative*) OR focus group*) OR meta-ethnography) OR case study) OR thematic analysis) OR framework synthesis) AND ((((empathy[MeSH Terms]) OR compassion[MeSH Terms])) OR ((empathy) OR compassion))) AND ((((((((((medical teacher[MeSH Terms]) OR medical faculty[MeSH Terms]) OR medical education[MeSH Terms] OR medical educator[MeSH Terms]) OR medical student[MeSH Terms]) OR medical undergraduate*[MeSH Terms])) OR ((medical) AND teacher)) OR ((medical) AND faculty)) OR ((medical) AND educator)) OR ((medical) AND student*)) OR ((medical) AND undergraduate*))) Filter: English

Table 3. Number of search results from each database used.

Database	Total hits
CINAHL	59
EMBASE	426
ERIC	29
PsycINFO	474
PubMed	466
Total	1454

Table 4. Study selection criteria used to guide the screening of articles.

Inclusion criteria	Exclusion criteria
Empirical study in English.	Students or faculty were from non-medical professions, therapy or healthcare therapy.
Paper published since and including year 2007.	Studies using a quantitative or mixed methods design.
Involvement of students enrolled in medical undergraduate studies and engaged in initial medical training regardless of their qualifications on entry.	
Study describes some form of education or teaching intervention or learning experience for the medical students.	
Study uses a qualitative study design.	

grid (Cahill et al. 2018). Next, the research studies were arranged chronologically and themes were translated using the key concepts or themes from each paper as suggested by Atkins et al. (2008). A line-of-argument synthesis was conducted to integrate the similarities and differences among the studies to produce a new conceptual model illustrating our interpretation of the findings. We had several discussions to clarify the key concepts and meanings identified, and created interpretations of these collaboratively (Cahill et al. 2018). Audit trails were also maintained to enhance the trustworthiness of the research findings. Preliminary concepts were derived individually by the reviewers and discussed extensively before the final third order concepts were finalized. An example of how this coding was conducted is provided in Supplemental Table 6.

Findings

The line-of-argument synthesis contributes to meeting the review's first aim of examining medical students', educators, and patients' perceptions and experiences of what affects empathy and compassion in medical students. The synthesis resulted in four main themes: Seeing the patient as a person; Appreciating the elements of empathy and compassion; Navigating in the training environment; and Being guided by ideals. Based on the medical students' and patients' perceptions and experiences, we suggest that in order to show empathy and compassion to patients, medical students need to develop and maintain the perspective of "Seeing the patient as a person" over the course of their medical training. Additionally, empathy and compassion are dynamic processes and relational in nature. By this, we mean that interactions between patients and students influence the demonstration of empathy and compassion. This is evidenced by students' and patients' accounts of how empathy and compassion were expressed and reinforced or suppressed by care recipients' emotions, words and actions. Besides that, the larger environment in which the patients, students and educators are situated

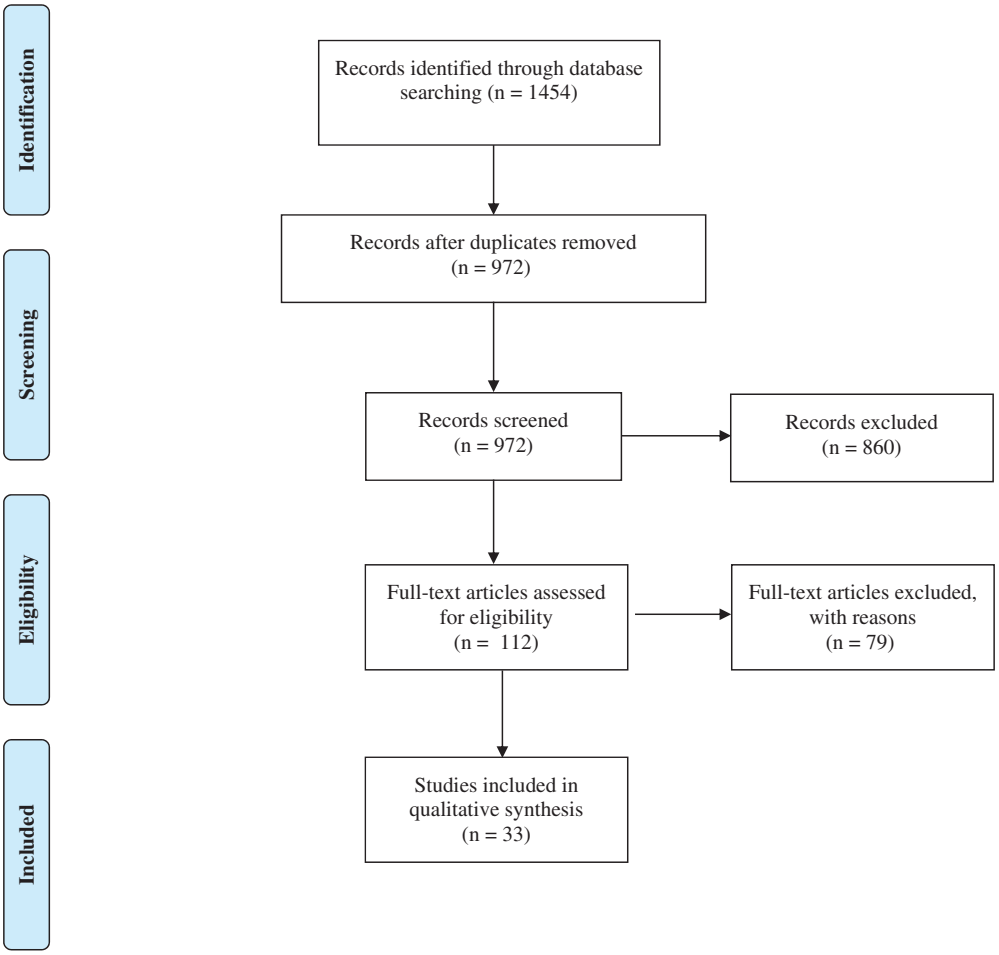

Figure 1. PRISMA 2009 flow diagram (adapted). From: Moher et al. (2009).

has a paramount influence on medical students' experiences in their attempts to learn and demonstrate empathic and compassionate actions. Finally, learning of empathy and compassion is also influenced by medical students' values and ideals. Supplemental Table 7 provides an overview of the main themes and sub-themes identified in all 33 articles. Supplemental Table 8 provides additional quotes to substantiate our themes and sub-themes.

In relation to the review's second aim, Figure 2 illustrates a model delineating the main themes described above and the interactions between the patient, medical student, and training environment. As illustrated in the model, all the components interact and affect medical students' learning of empathy and compassion.

Seeing the patient as a person

When medical students saw patients as people, rather than depersonalizing them, they were encouraged to have empathy for patients. Students in the studies recognized patients as a "person" (Kenyon and Brown 2007, p. 607; Klemenc-Ketis and Kersnik 2011, p. 3; Arntfield et al. 2013, p. 5; Burgess et al. 2015, p. 3; Boland et al. 2016, p. 488), "real person" (Boland et al. 2016, p. 488), "whole person" (Boland et al. 2016, p. 489), "people" (Kenyon and Brown 2007, p. 607; Ganesh and Ganesh 2010, p. 228; Konkin and Suddards 2012, p. 590; McNeill and Campbell 2013, p. 261; Beck et al. 2015, p. 1278), "human beings" (Kearsley and Lobb 2014, p. 76; Brand et al. 2017, p. 436) or "fellow human beings" (Head et al. 2012, p. 537), and as an "individual" (Allen et al. 2008, p. 261; Beck et al. 2015, p. 1279) or "individuals" (Chretien et al. 2015, p. 1027).

From their encounters with patients in platforms such as a medical apprenticeship, a rural clinical attachment and/or a longitudinal integrated clerkship, students also demonstrated an increased awareness that patients have personalities (Allen et al. 2008), are people "who live and play outside" (McNeill and Campbell 2013, p. 261) and have "jobs and have to pay their mortgage" (Konkin and Suddards 2012, p. 590). Through an elective course on professionalism using films, students also recognized empathy demonstrated by the nurse in the film when she regarded the patient "as a subject" and "saw her as a person who is breathing, thinking, hearing, seeing, talking, wanting, suffering and seeking support from other people" (Klemenc-Ketis and Kersnik 2011, p. 3). In examining perceptions and experiences, students also learned to not depersonalize patients, specifically not to see them as "an object" (Klemenc-Ketis and Kersnik 2011, p. 3) or to objectify them (Bandini et al. 2017). They also learned not to consider patients as an illness (Ganesh and Ganesh 2010; Arntfield et al. 2013), "disease" (Head et al. 2012, p. 537; Frazier et al. 2015, p. 4; Boland et al. 2016, p. 489), "cases" (Ganesh and Ganesh 2010, p. 228; Brand et al. 2017, p. 436), "set of symptoms" (Boland et al. 2016, p. 489), or "bed number" (Ganesh and Ganesh 2010, p. 228); and to not merely see them as opportunities for teaching or learning (Eikeland et al. 2014). Reflecting on a week-long clinical rotation in palliative care, a student experienced intense anger when he observed doctors treating a patient "like cattle" (Head et al. 2012, p.

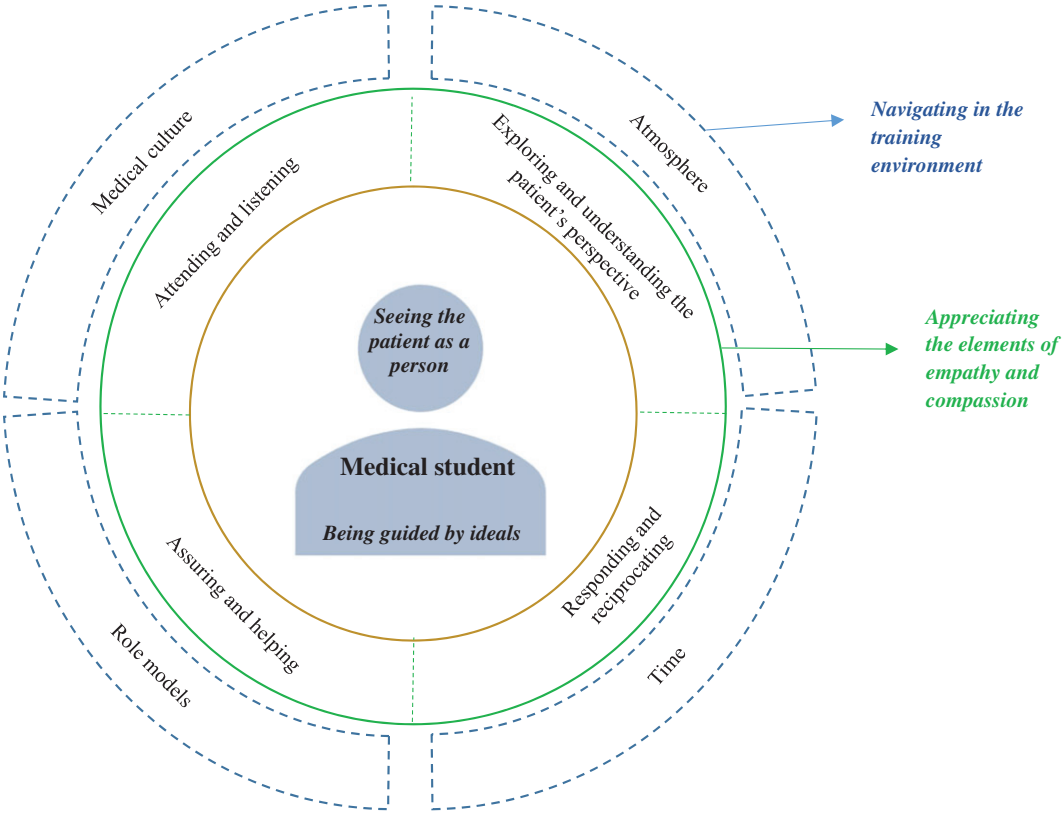

Figure 2. Model of interactions between the patient, the medical student and the training environment.

539). When the medical students saw the patient as a person, there was a desire to relate with the patient "on a human level." Reflecting on her clinical placements, a student wrote "Every patient has a real need to be treated as a real person and that no amount of knowledge will be useful if I cannot interact correctly with the patient on a human level" (Boland et al. 2016, p. 488). However, students also realized how "they often lost sight of the uniqueness of the individual" in the medical environment (Head et al. 2012, p. 539).

Appreciating the elements of empathy and compassion

In this next theme, medical students were described as being present and attending to patients, being curious about them and trying to understand their perspectives. This adds to an understanding of what affects empathy and compassion in medical students. The acts of medical students giving assurance and helping patients, and in turn, patients responding to this care, comfort, and help are also included in this theme. This theme includes interactions between medical students and medical care recipients but excludes interactions between students and other healthcare staff or professionals. In this theme, medical students learned to appreciate the different elements of empathy and compassion and their interpersonal nature.

Attending and listening

The perceptions and experiences of medical students, educators and patients were examined through how they devoted time and paid attention to and listened closely to patients, care recipients, as well as caregivers and families. Through interactions with them, students learned the importance of being present for patients (Head et al. 2012), spending time or taking time with them (Ganesh and Ganesh 2010; Frazier et al. 2015; Boland et al. 2016), and listening to them (Breytspraak et al. 2008; Ganesh and Ganesh 2010; Beck et al. 2015; Chretien et al. 2015; Frazier et al. 2015; Gonsalves and Zaidi 2016). During a narrative medicine intervention, students elicited illness narratives from patients and learned to "slow down and listen," making patients feel that they are a person: "sometimes we need to take a moment to just sit with someone and just listen … and make them feel like you know they're a person once again, that they're not an illness … " (Chretien et al. 2015, p. 1027). Listening to refugees while providing care triggered empathy in students (Griswold et al. 2007). Students also learned to express empathy and compassion by "just" listening to patients and caregivers (Atasoy et al. 2012, p. 659; Beck et al. 2015, p. 1279). In addition to making patients feel that they are persons, triggering empathy in students and allowing them to express empathy, listening to patients also helped students to understand patients' struggles with their conditions (Kastenholz and Agarwal 2016). Students were also able to learn the importance of listening in order to understand their patients through narrative medicine training (Arntfield et al. 2013); and reflecting on films (Klemenc-Ketis and Kersnik 2011).

Exploring and understanding the patient's perspective

This sub-theme involves understanding underlying concerns, causes, or issues pertaining to patients' and families' emotions toward medical care suggestions, decisions, or plans, as well as exploring the pain or suffering experienced from perceptions and experiences of medical students, educators, and patients. Students learned to explore

and understand the perspectives of patients (including care recipients and caregivers) by observing or relating to them. For example, continuity of patient care through a longitudinal integrated clerkship gave students the opportunity to understand the experiences and perspectives of patients and their caregivers, contributing to the students' compassion (Konkin and Suddards 2012). A student expressed that doctors are able to augment their relationships with patients in different contexts by considering patients' perspectives instead of just feeling sorry for them (Tavakol et al. 2012). Students learned to explore patients' perspectives by "using open questions and asking ideas, concerns and expectations" (Aper et al. 2015, p. 82); and by eliciting information about patients (Griswold et al. 2007). Understanding and empathizing with patients involved being nonjudgmental for some students (Batley et al. 2016; Kastenholz and Agarwal 2016). Other students drew on their life experiences to foster empathy and understanding toward their patients (Eikeland et al. 2014; Brand et al. 2017), but some were not able to: "Although I attempted to employ empathy, it was difficult because I had no idea what this man must be feeling. Before, I have always used empathy by trying to stand in the other person's shoes and mimic what I think they should be feeling. In this case, I just couldn't do that" (Boland et al. 2016, p. 488). When students found it hard to empathize without having experienced something similar to their patients, they may have had difficulty differentiating between sympathy and empathy (Tavakol et al. 2012).

Students were also able to learn to explore patients' perspectives without direct interaction with patients. Patient stories narrated during lectures promoted the patients' point of view and encouraged students to have empathy and compassion (Easton 2016). Creative writing allowed students to access an "otherwise alien experience and perspective and as a result feel genuine empathy and compassion" toward patients they may otherwise have been "quick to judge" (McDonald et al. 2015, p. 7). Through narrative medicine training, students learned to receive and value different perspectives to understand patients better (Arntfield et al. 2013).

Assuring and helping

The medical students also learned about comforting patients, care recipients, and caregivers. By relating with patients, care-recipients, and caregivers, students were motivated to assure and help them, and learned how to do so in different contexts. Students expressed being motivated to work hard to become great doctors in order to help children with diseases such as diabetes (Beck et al. 2015). This desire to help is also evident in one student reflecting on the experience in a voluntary community service organized in medical school, "This project has helped me mature in many ways, because it's a different point of view when you go back to the country you grew up in. You feel you're in the status where you are capable of helping people, that you have the ability to help people, so you want to help them more and more … " (Loh et al. 2016, p. 687). Students learned practical ways of assuring and helping like summarizing things (Allen et al. 2008), giving supportive words (Atasoy et al. 2012), smiling (Griswold et al. 2007), holding a patient's hand (Head et al. 2012), dispelling worries (Kastenholz and Agarwal 2016), and comforting (Ganesh and Ganesh 2010; Loh et al. 2016).

Responding and reciprocating

From the studies, when students demonstrated empathy, compassion or care, patients responded positively (Griswold et al. 2007; Allen et al. 2008; Ganesh and Ganesh 2010; Konkin and Suddards 2012; Lutz et al. 2013; Boland et al. 2016). In return, when patients responded positively to them, students were encouraged and found it easier to have compassion (Braun et al. 2013) and be able to practice "gentle medicine" (Head et al. 2012, p. 538). Students who interacted with older adults in a retirement community found that "the relationship is reciprocal" where each felt comfortable with the other (Breytspraak et al. 2008, p. 141). On the other hand, if patients were not responsive, students felt that they were not able to engage with them: "I … expected … all this emotion about his illness and we were going to connect … instead I kind of felt pushed away, and he wasn't even actually able to engage in a story about his illness." (Chretien et al. 2015, p. 1026).

Navigating in the training environment

The next theme, *Navigating in the training environment*, encompasses aspects of the environment that pertain to the teaching and training of medical students and how they impact the development of empathy and compassion in medical students. This includes their experiences in the training environment, and their perceptions of the considerations of time, medical culture, role models, and atmosphere.

Time

Time includes instances of efficiency, realities of time pressure as well as constraints experienced by the medical students or observed in those whom they learn from, and which impact on their expression of empathy or compassion. Students described the time constraints they experienced and concerns they had about losing the caring attitudes and behaviors they were taught because of the need for efficiency (Allen et al. 2008). "Some respondents described changes in behaviors based on efficiency and time management, but these changes were not always positive as some students noted their increasing impatience both in their professional and personal lives." (Bandini et al. 2017, p. 60). Time pressures also led to some students following the practices of more experienced clinicians, "I would not do it like that if I had more time … but you just have to do it the way your supervisor does it …." (Aper et al. 2015, p. 82); or accepting that which they initially had not, "At first, I was annoyed by some people here who are really cynical, but later on I noticed that they're actually still efficient, so now I don't mind the negative atmosphere … " (Batley et al. 2016, p. 4).

Medical culture

Medical culture includes mention or emphasis on scientific or medical knowledge, or medication or other treatment. It also includes constraints on the expression of emotions,

empathy or compassion due to different discourses about emotions and their role within the prevailing medical culture. In addition, the norms and values of the medical culture may also be inferred from the content and structure of the medical curriculum, activities, and assessable topics.

The focus of the medical culture on medical knowledge over humanistic qualities is exemplified in this quote from Michalec (2011) "From the interviews with preclinical students it could be argued that many students did not see the psycho-social aspects of patients as 'real things' that they need to learn. They may feel that clinical empathy is important to engage in and is an important ingredient in positive doctor-patient relations, as a majority of them expressed during their interviews, but given that it is not formally evaluated, and that the discussions of these topics declines over the course of the year, students focus more intently on what is truly valued by the institution, that which *is* tested and consistently addressed in small groups, labs, and lectures" (p. 125). Klemenc-Ketis and Kersnik (2011) reported how the medical students involved in learning professionalism though films emphasized the development of scientific and medical knowledge over humanistic qualities in the doctor's management of their patient in one of the films, which was considered to be "one-sided and purely bio-medically founded" (p. 3). This emphasis was also thought to be a problem in other studies, for example, "This disconnect likely arises out of the methods used for training which are viewed as counter-culture, a problem that is common to humanities-based programs in medicine [46]" (Arntfield et al. 2013, p. 9).

Despite this, one medical student identified a need to maintain a balance between empathy and distance during patient–physician interactions: "There is a limit. You have to be empathetic, but you cannot be too empathetic, and again, this should come with experience; to know at which point you should stop being too involved with the patient, and at which point to engage more … " (Batley et al. 2016, p. 4). This balance was also mentioned by Ganesh and Ganesh (2010, p. 228): "Students need to find a balance between being challenged by investigating a patient's medical condition – the science of medicine; and at the same time not being divorced from the person they are treating – the emotional side of medicine." Several of the papers discussed ways in which medical curricula and activities could be structured to help balance the development of medical knowledge with nurturing the humanistic qualities of doctors. In Kenyon and Brown (2007) for example, the experience of having a mission statement day promoted reflection on the values that motivated students to study medicine, "It really sets the tone for the entire medical school but it would be useful to incorporate that tone a little more throughout. It's pretty unique. I've never had that experience before and I probably never will again. It was such an intense soul-searching emotional experience. It was great." (p. 609).

Role models

Role models includes those who are involved in shaping the learning and development of medical students, including staff, faculty, patients, or others involved directly or indirectly in their medical training. Positive and negative role modeling are also included in this sub-theme. The tutors served as role models in showing empathy, and occasionally some tutors showed how it should not be done (Boland et al. 2016, p. 489). An example of positive role modeling included a reflection by a medical student following observations of communication between physicians, patients, and relatives, as well as between relatives and staff, "I understood that being a physician is not consisted of just studying or having an ordinary profession and that it requires the formation of the wish to help the others and of empathy skills." (Atasoy et al. 2012, p. 659).

Atmosphere

Atmosphere encompasses physical and nonphysical aspects of the environment that have an effect on the development of students' empathy and compassion, including consideration of aspects of the environment that can be changed or improved.

Medical tools and appliances may have the effect of creating a medical atmosphere and homogenizing or objectifying patients (Allen et al. 2008, p. 262). Students experienced cognitive overload when they had to manage both the biomedical and communicative aspects of a consultation and perceived that this made it more difficult to demonstrate empathy (Eikeland et al. 2014; Aper et al. 2015). Having a reflective space and open dialog improved students' emphatic skills and ability to cope with difficult situations (Ganesh and Ganesh 2010; Arntfield et al. 2013; Lutz et al. 2013; Brand et al. 2017).

Being guided by ideals

This theme espouses the idea that underlying and intrinsic thoughts, motivations, and ideals the medical students had influenced their identities and how they developed and responded in the various learning situations and environments they were in. For instance, students were disappointed or angry to see consultants not showing respect and not spending time to understand patients' difficulties and felt powerless that they could not defy educators' instructions or the over-emphasis on medical knowledge in medical culture though they knew their actions were not in patients' best interests (Allen et al. 2008; Tavakol et al. 2012; Burgess et al. 2015; Frazier et al. 2015). Others felt guilty for being unable to relieve patient's suffering (Ganesh and Ganesh 2010). The following example shows the dilemma experienced by a student who wanted to provide comfort and relieve patient's discomfort but was stopped by his/her medical educator: This student wanted to demonstrate empathy toward the patients in ways that she was not allowed, for example by attending and responding to care needs. "There are some of the elderly patients (…) that ask if someone can cut their nails (…) My idea of empathy is that that is something I could have done, (…) I changed the bedding for a patient who had vomited (…) then I was told," "Then you should call the nurse because she's supposed to do that," because we were seven people, we were supposed to interview (…) and I thought, "Well, there's only two people talking. I can do this in the meantime." (Eikeland et al. 2014, p. 4).

Medical students' values and ideals also appear to affect what they chose to focus on in their training environment.

Medical students chose to model doctors who are aligned with their own ideals of the physician's role. Students who valued problem-solving and evidence-based medicine, viewed clinicians with high clinical efficiency as their role models, while those who valued patient care, modeled themselves on clinicians' compassionate behavior (Aper et al. 2015; Bandini et al. 2017). Students' values also influenced their perception of learning about psycho-social aspects of patient care. Some students found little value in learning the psycho-social aspects of patient care in lectures and small group discussions in their first year of medical school. They described the content as "that touchy-feely stuff" and stated that they preferred to "focus on the real things" (Michalec 2011, p. 125). The provision of early positive experiential learning experiences, i.e. opportunities to interact with patients may influence their perceptions over time (Kastenholz and Agarwal 2016). In addition, students who attended workshops that promote development of self-awareness and reflection on their personal and professional experiences found "a renewed sense of drive and enthusiasm" for medicine (Kearsley and Lobb 2014, p. 77). Reflection, along with experiential learning allows students to consolidate their thoughts and develop into the kind of doctor they want to be (Boland et al. 2016).

In summary, medical education affects empathy and compassion in students in multiple ways and through different means. Learning activities that allow students to recognize patients as unique individuals and fellow human beings (e.g. creative writing, films, longitudinal integrated clerkship) promoted development of empathy and compassion. Opportunities to interact with patients have the added advantage to promote and reinforce expression of empathy and compassion. Medical students learned about the interpersonal nature of empathy and compassion through patient interactions by having the opportunity to listen, explore patients' perspectives, help patients, and receive responses from them. The development of empathy in students is also affected by the external training environment, including the emphasis on medical knowledge, time pressure, negative role models, and aspects of the environment that depersonalize patients. Moreover, students ideals of the doctor's role not only shape how they respond to situations that appear to contradict their ideals, these ideals also affect what students choose to focus on in their training, thus affecting their development of empathy and compassion. Reflection exercises allow students to pause and contemplate on their experiences and remind students of the importance of empathy and compassion.

Discussion

This meta-ethnography aimed to build a new interpretive account from the primary qualitative studies to understand how education affects empathy and compassion in medical students. Our conceptual model in Figure 2 illustrates how medical students' perspectives and ideals, their appreciating of the interpersonal elements of empathy and compassion, as well as their training environment are aspects that all play a part in how education affects empathy and compassion in medical students.

Medical students' perspectives of *seeing the patient as a person* are seen to play a central part in how education affects empathy and compassion in students. It may be developed primarily through learning activities involving interactions with patients as well as narrative approaches such as creative writing and videos. Although both learning approaches allowed students to see patients as individuals rather than objects, it appears that students recognized that they may lose this perspective only when they were given an opportunity to interact with patients within the medical environment. Students realized that they may lose sight of the uniqueness of their patients as individuals while navigating in their fast-paced training environment as they encountered conflicting messages between taught values and observed behavior. For instance, time pressures experienced in the clinical setting led students to model after experienced, efficient clinicians and lose the perspective that patients are people. Students also struggled to maintain a balance between empathy and distance with their patients as they were constantly reminded by their educators to suppress their emotions and behave "professionally."

The ideals of medical students that guide them during their training are also seen to be central. Mastering biomedical skills and knowledge undoubtedly formed a substantial part of students' ideals of the doctor's role; nonetheless, these ideals potentially limited students' practice of empathy. Medical students' ideals of the doctor's role also influence the extent to which they internalized empathy and compassion. This shaped how they responded to and interfaced with the various individuals and environmental factors that they encountered in their training. Some students found little value in learning about the psycho-social aspects of patient care and preferred to focus on biomedical knowledge in the first year of medical school. Our findings echo Pedersen's (2009) recommendation to take into consideration biomedical paradigms and learners' professional priorities and structure empathy training beyond the dichotomy between biomedicine and the humanities. Guided reflections incorporated in teaching activities allowed students to pause and contemplate on their experiences of empathy and compassion. The provision of opportunities for medical students to voice their concerns helped them clarify their thoughts on observed behaviors that they perceived to be misaligned with their ideals and standards.

Appreciating the four interpersonal elements of empathy and compassion (i.e. Attending and listening, Exploring and understanding the patient's perspective, Assuring and helping, and Responding and reciprocating) is another core aspect. Current trends in medical curriculum appear to focus predominantly on developing students' skills in active listening and thinking from the perspectives of patients. However, empathy and compassion are dynamic processes. The expression of empathy and compassion is relational in nature and emerged in interactions. When patients reciprocated to expressions of students' empathic and compassionate behavior, the students were in turn encouraged, and found it easier to express empathy and demonstrate compassion. Main et al. (2017) highlighted the interpersonal and relational nature of empathy, with empathy being a dynamic process that is highly dependent on the characteristics of the person being empathized with, the relationships between the

interacting persons and other contextual elements. Our findings support the approach of conceptualizing empathy as "not a finite point in time of mutual affective experience, but rather as a dynamic process that involves cognitive and emotional discoveries about others' experiences" (Main et al. 2017, p. 358).

As illustrated in our conceptual model, the medical student navigates his training environment while being guided by his ideals, shaping his perspectives about patients and learning to appreciate the elements of empathy and compassion. We identified aspects of the training environment that have an impact on this process. In his meta-ethnography of interview-based studies, Jeffrey (2016) identified that a strong emphasis on the biomedical over psycho-social elements of care may create a barrier to empathy. On top of the emphasis on biomedical knowledge, we found that time pressure, negative role models, and the objectification of patients can affect students' perspective of seeing patient as a person and learning to appreciate the different elements of empathy and compassion.

In relation to the third aim of the review, important considerations that medical educators and faculty developers could have in developing medical curricula include using existing curricula and providing students with opportunities to interact with different types of patients in different settings while encouraging the students to be genuinely interested in the patients as persons. This is because, as medical students interact with their patients with empathy and compassion, patients may reciprocate, and this in turn can encourage students to express compassion. This negotiation and establishment of a dialog between a clinician and patient can reinforce the relational aspects of empathy and compassion; it allows for the co-creation of patients' stories with professionals and identification of steps that can be taken in the care environment (Avrahami and Reis 2009). Educators could also consider broadening the definition of empathy to also consider empathy as a relational construct, to incorporate shifting focus from teaching the "*form* of empathy" to the "relational *functions* of empathy" in interpersonal contexts, i.e. considering how receptive the person being empathized with is, and the contextual elements that may influence the interactions (Main et al. 2017, p. 364). Although approaches like creative writing and films do not provide the opportunity for students to interact with patients, we found they helped students appreciate the interpersonal nature of empathy as well. As these approaches are limited when students do not interact with patients, we recommend they are complementary to, and not a substitute for, other more patient-focused opportunities. Lastly, it is imperative that good values and ideals are encouraged and supported through for example clinicians and educators demonstrating professionalism and exemplary behaviors that medical students can model, acknowledging that everyone working in a clinical environment is a role model. Students should also be provided opportunities to reflect and share their concerns if any, or to clarify their thoughts or reflections on observations and behaviors that they perceived to be not aligned to the ideals and standards they have.

The majority of the papers included were of reasonable quality as rated on the CASP (2014). The papers either did not provide information on the relationship between the researcher and participants or it was not clear what their relationship was. However, the papers had clear aims, and the methodology used was appropriate to achieve their aims. Ethical issues were considered in the studies and appropriate strategies were used for participant recruitment and data collection. Data analysis seemed appropriate and rigorous, and clear results were stated in the majority of the papers included.

Implications for future research

Future research could consider the interrelationships and interactions among the components of empathy and compassion that medical students are exposed to as part of their training. By studying all of these proposed components together, one might be better able to understand the nature and nuances of the mechanisms in which empathy and compassion present. A clarification of the understanding of the findings could also suggest implications and applications, such as whether these individual or combined components contribute to change in medical education, and the development of medical professionals who are better able to express and manage their empathy and compassion and during interactions with patients, caregivers, and staff. Future research could also investigate the development of medical students' sensibility to language, interactions, or communication, and their narrative competence in skills such as active listening, reading, and reflective writing, which could potentially impact on their expression of empathy and compassion in the healthcare context.

Limitations

The data on which the analyses were based were as reported by the authors of each paper, hence understanding of the phenomena may be limited as the quotes and themes, while generally assumed to be representative of the key themes and findings in each empirical study, may have been limited by word counts or selective reporting by authors. Although the studies were from a range of countries including Turkey, Australia, the USA, and Canada, it was difficult to compare the findings between studies because differences in contexts, geographical locations, health care systems and structures may have affected how each educational program was provided, or experienced by the students. Additionally, gray literature were not searched for and included in this review.

Conclusions

This meta-ethnography helps deepen our understanding of how medical students learn about empathy and compassion in various intensive training formats in a dynamic training environment. We showed how medical students' perspectives and ideals, their appreciating of the interpersonal elements of empathy and compassion, as well as their training environment all play a part in how education affects empathy and compassion in medical students.

Disclosure statement

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Glossary

Empathy: Is considered as a process, involving the ability to understand the patient's situation, perspective, and feelings and to communicate back that understanding, and to act on that understanding in a helpful (therapeutic) way (Mercer and Reynolds 2002).

Compassion: Is "built on the capacity to empathize – a form of cognitive and emotional perspective taking – but involves the additional step of wanting to alleviate suffering" (Fernando et al. 2016, p. 340).

Medical student: Persons involved in medical, undergraduate studies and engaged in initial medical training regardless of their qualifications on entry.

Education: Includes medical education curricula and activities medical students engage in, in a variety of learning environments that could include classroom, bedside teaching, homework, interactions with patients, etc.

Educators: Include medical teachers, faculty, and persons involved in teaching medical students, e.g. patients.

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RESEARCH ARTICLE Open Access

What makes an online problem-based group successful? A learning analytics study using social network analysis

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Abstract

Background: Although there is a wealth of research focusing on PBL, most studies employ self-reports, surveys, and interviews as data collection methods and have an exclusive focus on students. There is little research that has studied interactivity in online PBL settings through the lens of Social Network Analysis (SNA) to explore both student and teacher factors that could help monitor and possibly proactively support PBL groups. This study adopts SNA to investigate how groups, tutors and individual student's interactivity variables correlate with group performance and whether the interactivity variables could be used to predict group performance.

Methods: We do so by analyzing 60 groups' work in 12 courses in dental education (598 students). The interaction data were extracted from a Moodle-based online learning platform to construct the aggregate networks of each group. SNA variables were calculated at the group level, students' level and tutor's level. We then performed correlation tests and multiple regression analysis using SNA measures and performance data.

Results: The findings demonstrate that certain interaction variables are indicative of a well-performing group; particularly the quantity of interactions, active and reciprocal interactions among students, and group cohesion measures (transitivity and reciprocity). A more dominating role for teachers may be a negative sign of group performance. Finally, a stepwise multiple regression test demonstrated that SNA centrality measures could be used to predict group performance. A significant equation was found, $F(4, 55) = 49.1$, $p < 0.01$, with an R2 of 0.76. Tutor Eigen centrality, user count, and centralization outdegree were all statistically significant and negative. However, reciprocity in the group was a positive predictor of group improvement.

Conclusions: The findings of this study emphasized the importance of interactions, equal participation and inclusion of all group members, and reciprocity and group cohesion as predictors of a functioning group. Furthermore, SNA could be used to monitor online PBL groups, identify important quantitative data that helps predict and potentially support groups to function and co-regulate, which would improve the outcome of interacting groups in PBL. The information offered by SNA requires relatively little effort to analyze and could help educators get valuable insights about their groups and individual collaborators.

Keywords: Learning analytics, Data analytics , Social network analysis, Social networking, Problem-based learning, Online learning, Small groups

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Background

Problem-based learning (PBL) as an approach to instruction has attracted much attention across disciplines in higher education. PBL was first developed in medical education in the 1950s to respond to the criticism that traditional teaching methods fail to prepare medical students for solving problems in clinical settings [1]. After the successful development of PBL in various fields of medical education, it is now being implemented in higher education, professional education as well as in K–12 education [1, 2]. According to Hung, Jonassen, & Liu (2008), the rationale for PBL lies in its compatibility with modern educational goals such as the education of self-directed and life-long learners who can solve real-life problems in collaboration [1]. Nowadays, when researchers discuss twenty-first-century skills, they often emphasize key elements of PBL, such as being able to communicate and collaborate to solve complex problems, being able to adapt and innovate in response to new demands and changing circumstances, and being able to use technology to build new knowledge [3].

PBL originates on constructivist conceptions of learning by assuming that knowledge is constructed by the learners in their interactions with the environment [4, 5]. Since knowledge cannot be directly transmitted, PBL instruction should consist of learning activities and environments that facilitate knowledge construction [5]. The principal idea behind PBL is that the subject matter content and skills to be learned are organized around shared problems, rather than as a hierarchical list of topics delivered by the teacher [1]. In PBL, the students need to articulate the problem and then to search, evaluate, construct and share information, and apply it in the context of the problem-solving process at hand [6]. Accordingly, the ability to make insightful and productive use of the learning resources is playing an important part in PBL method [1, 6]. This is to say, PBL often challenges students, since it requires learners to engage in self-regulated learning [7], that includes, for example, ability to purposefully regulate own cognitive, motivational, and emotional behavior as well as that of others for optimal learning [8].

Collaborative learning is the second key element of PBL [9, 10]. By working together in small groups, students are expected to actively communicate, share their expertise and previous knowledge, make joint decisions, negotiate responsibilities, as well as to evaluate and modify the strategies of learning and group work through interactive dialogue [11]. As such, conceptualizing PBL and collaborative learning has also been influenced by sociocultural theory, which emphasizes the pursuit of a common goals through interpersonal interactions [12, 13]. From this perspective, individual group members represent interdependent self-regulating agents who at the same time constitute a social entity that creates affordances and constraints for group and individual learning [14].

Moreover, previous studies have shown that the success of collaboration relies on coordinating collaborative actions toward a shared goal [15, 16]. This is to say, in successful collaboration, each student needs to be in charge of their learning, coordinate their peer learning, and also coordinate the group learning as a whole [17]. This requires communication such as construction and pursuit of a shared object and collaborative planning [14, 18, 19], including search for common ground [16, 20], negotiation of roles and responsibilities [13], as well as distribution and organization of workload [13, 15]. Furthermore, collaborative learning requires equal team member participation that leads to advances and co-elaboration of the knowledge objects at hand [16, 21]. In other words, this type of interactional achievement is realized through shared epistemic agency, which emphasizes a capacity that enables individuals and groups to make appropriate judgments, to make plans and to coordinate the contributions toward joint outcome [16, 21]. Although there are substantial differences in conceptualizations of these intersubjective interactions and how these constructs are interpreted and defined, there seem to be an agreement that shared knowledge and joint cognitive responsibility are an essential aspect of coordinating and monitoring work in productive collaboration.

While research has shown that PBL can enhance, for example, interpersonal skills, communication skills and collaboration skills [22, 23], organization and dynamics of collaborative learning also impose many challenges for students and teachers as well [24]. Students may suffer from poor interaction and contribution of its members, the dominance of some members, poor time management, and focus on peripheral issues rather than the core of the problem under investigation [13, 14] If these challenges are not adequately addressed, they may cause student disengagement, task avoidance, dysfunctional group dynamics, and even withdrawal of one or more actors [13, 24, 25].

To summarize, there is a wealth of research on PBL that has helped understand many aspects and elements of collaborative learning. However, it is challenging to capture and support PBL with current instrumentation as they require time and efforts coding interactions, interviewing students, or surveying their responses. Furthermore, the current methods cannot be implemented to deliver automated analysis and insights for educators. Providing automated ways of analyzing and reporting about group functioning would help teachers offer better support for students, and focus on their teaching duties.

Accordingly, there is an evident need for methods, such as Social Network Analysis (SNA), that makes the

collaborative aspects of the PBL process visible. SNA as a method provides automated monitoring and analysis of large volume of interactions, and requires little effort or manual intervention from educators. This study is trying to test the potentials of SNA in analyzing group functioning and to report which variables can help educators. The coverage of social network analysis will be introduced in the SNA section.

Social network analysis

A social network is a group of connected entities through a relationship. Examples include a group of friends, collaborating companies, interacting union members countries, and extend to animal herds, proteins, genes, etc. Social network analysis is a group of methods that are used to study these connections. The entities are called "nodes", "actors" or "vertices" and the relationships are called "links" or "edges". SNA enables the study of how the relationships influence the behavior of the connected members, and how the structure shapes the embedded members. Proponents of the methods argue that the study of the structure and relationships could help understand learning, visually and quantitatively in a way not offered by the other qualitative methods [26].

Using SNA a researcher can map the patterns of interactions, highlight the active, the inactive and the isolated students. SNA could be also used to identify the roles of interacting students, for example, to identify the leaders, the moderators and the dominating participants. Furthermore, SNA analysis could be used to quantify interactions, positions of interacting actors, and the structural properties of their groups [27, 28]. This is usually done through the calculation of "importance" measures known as centrality scores, since importance may have different meanings in different situations, there are multiple centrality measures that quantify various perspectives. For example, indegree centrality is a measure of inbound interactions, closeness centrality is a measure of reachability by all collaborators. These measures have the potential to be used to describe collaborators' behavior as well as their groups. Quantitative SNA may reveal important information also about the cohesion of groups, the flow of information and social capital. SNA could also offer a feasible and practical way of monitoring interactivity in collaborative settings. Furthermore, insights generated through automatic monitoring of interactions could serve as a basis for a learning analytics platform [29]. A further discussion of SNA metrics and interpretation will be presented in the methods section.

SNA in healthcare education

SNA has become increasingly popular as a tool within the learning analytics ecosystem, however, studies of SNA in healthcare education are relatively limited compared to other methods [29]. Some examples exist, such as investigating the potentials of using SNA in PBL scenarios. For example, researchers have used SNA techniques to identify the roles of the students and tutors to get insights about gaps in the collaborative process, or use the centrality measures to predict performance using learning analytics methods [30–32]. While adding to our understanding of the process, these studies focused on the individual collaborator not the group as a unit of analysis. Some examples come from other domains such as [33], who created a recommender system based on group interactivity. Researchers used data from eight engineering courses and compared centrality measures to average group grades to recommend a better team composition [33]. Another example from Engineering used SNA to investigate the correlation between a team's project score and the team balance; their results pointed to a positive correlation, although, the sample size was small [34].

This leads us to conclude that there is a gap in studies using quantitative methods, i.e. SNA and learning analytics to monitor, evaluate and provide insights for teachers who wish to provide support and feedback for their students. This study investigates the group as a unit through the lens of SNA and learning analytics. Our research focuses on the group dynamics, and how the elements of the PBL process influence the outcome of the group as a whole and the participating students.

The research questions of this study are as follows:

1. How do the groups, tutors and individual student's interactivity variables of online PBL correlate with group performance?
2. Can the online PBL interactivity variables of the group be used to predict group performance?

Methods

Participants

Participants of the study were 598 participants (563 s-year dental students and 35 tutors). The courses were Body Health (teaches basics of physiology, pathology and disease of body health), Surgery (teaches foundations of surgery and common surgical principles), Neuroscience (teaches basics of nervous system physiology, histology pathology and common diseases), and Principles of Dental Sciences (teaches basic principles of dental sciences). The courses were repeated over three iterations in the year 2015, 2016, and 2017. Altogether, the participants worked in 60 groups (7 to 11 students and one tutor), mean = 10.6 students in each group.

Context

The study was done in the Qassim University, College of Medicine in Saudi Arabia, which has adopted the PBL

curriculum. The PBL tasks were open-ended scenarios, to provide a stimulus, for example a real-life clinical cases or problematic situations that are relevant in students' future profession [1, 6]. The PBL process, which was organized similary for all courses, was structured as steps that occur on a weekly basis. Students are assigned randomly to small groups with a teacher on each course. On the first day of the week, students gather in a face-to-face meeting (2 h) where the group (with the teacher) has to clarify the terms, then they need to identify the problem, and formulate the learning objectives. Then the online stage takes place for the whole week. Working online in a threaded forum in the Moodle online learning management system, students are supposed to share their learning, debate, argue, refine together to reach a common understanding. At the end of the week the students synthesized and wrapped up their learning in another face-to-face session (2 h) [9]. At the end of the course, the students had an exam that measured their learning and understanding of the PBL topics. The university used the Moodle learning management system forum module and each PBL group had a separate online forum for each week. Online PBL was introduced to harness the potential of asynchronous collaborative learning that would give the student a platform for continuous interactions and engagement [35].

Data

The data consists of Moodle logged written interactions from of 12 courses lasting for 7 to 8 weeks each. The interaction data were retrieved from the Moodle online system using custom database queries. The data retrieved includes the user ID, roles, grades, interactions and the metadata associated with each interaction (post author, group, course, thread, timing, subject, content, replies, and their metadata). Only interactions of the online PBL interactions were included. Posts related to announcements, course organization, or course questions were excluded. The terms user, actor or node are synonymous and therefore we will use the term user for simplicity throughout this paper.

Data preparation

The collected interactions data were structured into a format compatible with the SNA analysis software the Igraph R! library [36]. To build the networks, edges were reconstructed from each post by considering the author of the post as the source and the replied-to-user as the target, and then all edges were aggregated into a full network for each group. The networks were *simplified,* so duplicate identical interactions between two nodes and self-replies were concatenated and were used as a weight for each edge. This approach preserves the network structure and interaction information while simplifying visualization and mathematical analysis.

Data analysis and reporting

SNA analysis

There are three main components in the PBL process, the students, the tutors and the small group they are assigned. Therefore, the SNA analysis was done on these three levels: the individual user level (students and tutors) and on each group network level. The user-level analysis was done to calculate user activity metrics that reflect the quantity of interactions as well as the variables that reflect the user's position and role in information exchange [37–40]. The variables that were calculated were as follows:

Individual-level variables

Quantity of interactions metrics: these metrics reflect how much a student has posted or replied and may be known as interaction analysis metrics.

Outdegree: Outdegree is the number of interactions by an user. It reflects the user's effort, participation and social presence in the group [40–42].

Indegree[1]**:** Is the number of incoming replies or posts targeting a user. A user may receive a reply to an argument when it is worthy a reply; i.e. initiates a debate, opens a discussion or an argument. It is a reflection of the worthiness of a user's interaction as evaluated by peers [37, 40, 41, 43].

Closeness centrality: Closeness centrality, is a measure of the distance from all others in the group, it represents the degree of connection and involvement in the discussion. Isolated actors tend to have low closeness centrality scores, and involved actors have higher scores. Two variants are calculated for directed networks, the closeness in for incoming interactions and closeness out for outgoing interactions [37, 40, 41].

Betweenness centrality: the number of times a user has connected participants, therefore, bridging them and relaying the information [40, 41].

Eigen centrality: measures the number as well as the strength of connections, a user connected to well-connected users would have higher scores [44].

Hubness score: based on the concept of Eigen centrality, however, it is directional and represents the value of connections to well-connected authorities and important users [44].

It is important here to mention that indegree and outdegree centralities were divided by the group number to account for variations in the number of group participants. All centrality measures including indegree and outdegree were scaled per course (from 0 to 1), to eliminate the course variations.

Group level variables

The small group acts as a networked system for information exchange. Thus the properties of the network of interactions may reveal important insights that may help teachers and learning designers. The calculated properties of each group represent group size, interactivity, cohesion and efficiency as a medium for interaction and information exchange. The calculated variables were the following:

User count: number of actors in each group.

Edge count: number of edges[1] in each group.

Mean distance measures the reachability and ease of communication among group members, it is calculated by averaging the shortest paths among all group members. A higher distance indicates the presence of distant and isolated members of the group [38].

Centralization: centralization measures the distribution of a centrality score among actors in the same network. Therefore, indegree centralization is a measure of how incoming interactions are distributed among group members if a single user is receiving all interactions, the score is 1, a collaborative participatory network would have low scores. Similarly, outdegree centralization reflects the distribution of outgoing interactions in a group, centralization betweenness reflects the distribution of betweenness centrality, and so is centralization closeness [43].

Transitivity: the relative quantity of transitive friends, or how group members are connected through shared friends (forming a triangle), transitivity is a reflection of group cohesion [45].

Reciprocity: the ratio of interactions that are reciprocated. Interactions in collaborative participatory networks are reciprocated [45].

To further describe the group, we calculated the average centrality measures of individual members. Mean and median outdegree centralities represent the average quantity of interactions in the group. Mean and median indegree centralities represent the quantity of replies. Mean betweenness indicates the average brokering and mean closeness represents the average reachability of all group members.

Performance

The performance of students was measured as the sum of the PBL grades. The PBL performance (20% of the grade) is assessed by the teacher according to student's contribution to the PBL discussions each week. To increase uniformity, all groups are assessed by a single teacher each week. The second grade (80% of the grade) comes from the written exams (multiple choice and short essay questions) which tests the knowledge acquisition of the PBL objectives that were the subject of the interactions. Since grades comes from different courses, they were all standardized to eliminate the influence of course assessment variations. An ANOVA test was performed to test the difference among students' mean grade in the included courses and showed that no statistically significant differences (ANOVA ($F(11,551) = 0$, $p = 1$)). The Levene's test was performed to test for homogeneity of variance and demonstrated that the data did not violate the assumption of homogeneity.

Since there is no way to directly assess group performance, we used three measures

1. The mean normalized PBL grade of individual group members as a way of assessing the average grade of the group. Similar to [34].
2. The mean of each student's difference between own grade (normalized per course) and normalized GPA of the past six courses before the year of the study to have a uniform baseline, to see if the student did better than their usual baseline.
3. Additionally, we included the fraction of improved students (number of improved students divided by number of students in the group) of the students who performed better than their GPA (normalized per course).

Data analysis

SNA analysis was performed with Igraph library [36]. Each group data was considered a network, and were prepared for statistical analysis. The data were analyzed using R programming language [46]. Since many of the SNA variables did not follow a normal distribution, correlation tests were performed using Spearman rank correlation (Spearman's rho). The R! library 'StepReg' was used to perform the Stepwise multiple linear regression [47]. Ten-folded cross-validation was performed to validate the model. The model was evaluated with Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Mean Absolute Error (MAE) and R-squared. The level of significance for this study was set at 0.05.

Results

Descriptive statistics

In terms of online discussions of the group, the mean average distance was 1.51 (± 0.27), which is a short distance. In the case of online discussions, it could indicate that most students were close to reach and communicate. The mean reciprocity was 0.65 (± 0.22), indicating that most of the students replied to each other. The average indegree centralization was 0.27 (± 0.12), indicating that the replies were mostly distributed among

[1]Edge is basically a single post or an interaction as defined in detail in the data preparation section. We use the word interaction synonymously for simplicity.

Table 1 The network variables and characteristics of the interacting PBL group networks

Variable	Median	Mean	SD[a]	25th Percentile	75th Percentile
Edge count	177.500	214.3	164.318	85	274.250
Unique edges (simplified)	41.500	47.95	30.412	23	78
Mean degree	16.444	23.502	22.647	6.208	34.712
Mean distance	1.537	1.51	0.275	1.239	1.739
Transitivity	0.667	0.576	0.326	0.245	0.902
Reciprocity	0.690	0.651	0.216	0.522	0.817
Centralization in degree [b]	0.249	0.266	0.121	0.174	0.341
Centralization out degree [b]	0.453	0.488	0.265	0.220	0.7
Centralization Betweenness [b]	0.131	0.225	0.193	0.047	0.325

[a]SD, [b]Lower values are better

students. However, mean outdegree centralization was 0.49 (± 0.27), indicating the presence of active members of some groups who participated more than others (hubs or leaders). Betweenness centralization was also quite low (0.22 ± 0.20). Table 1 lists the mean, median and standard deviation of group variables. The table also lists the 25th and 75th percentiles. Groups that has values below the 25th percentile have relatively low interactivity reflected as low quantity of interactions, low reciprocity and higher values of centralization indicating dominant actors.

Figure 1 shows two groups of the dataset, group A is relatively inactive compared to group B, the Tutor – marked as T- is dominating, the visualization shows that the tutor in group A has more outgoing arrows (interactions) to most group members and so the tutor has high outdegree centralization. On the other side group B is interactive with interactions among most group members and the tutor. The SNA visualization is thus a powerful tool in showing how a group is doing and the relational aspects of interactions among group members. The mathematical or quantitative SNA analysis gives a more in-depth view of the roles in a quantitative way, that could help in a learning analytics context. We detail such analysis in the next sections.

Correlation between group network properties and performance

Looking at how different properties of PBL group correlates with student's performance we found that there was a significant negative correlation between the number of students in a group and the average normalized grade of the group ($r(58) = -0.29$, $p = 0.02$), however, it was statistically insignificant when correlated with change in grade or fraction of improved students. This negative correlation should alarm course designers of the size of groups, as it may be a hindrance to learning.

The quantity of interactions[2] in a group was significantly positively and moderately correlated with higher group's grade, positive change in grades, and fraction of improved students.[3] Furthermore, Group cohesion measures (transitivity and reciprocity) were all associated with better performance, positive change in grades and a higher ratio of improved students. That means that the quantity of students' interactions[1], replies to each other, and a broader base of participants of each group, is associated with a well-performing group and points to a functional group dynamic.

Contrary to signs of group cohesion, centralization measures were negatively correlated with the three performance measures (average group performance, change in performance or ratio of improved students). That was most obvious with centralization outdegree. An indication that when posting is concentrated or dominated by a few participants, it is not associated with better grades of the groups, or may be a sign of a dysfunctional group. Indegree centralization was also negatively correlated with lower average grades, but not as marked as the outdegree. Closeness and betweenness centralization (dominance of brokerage roles) were consistently negatively correlated with the three performance measures. In summary, an interactive cohesive group, that is not dominated by a member, and that have diverse participation among participants, is a group that is expected to score higher, have a positive change of performance and would help the higher ratio of students improve. These variables could be used as indicators for group function in a dashboard, that easily show the teachers the signs or red flags for a group that may need support. Table 2 has detailed statistics of all correlation results.

[2]Please note that the indegree and outdegree were weighted by group size and normalized.

[3]Please note that all grades were normalized per course, and so the grades cosidered everwhere in the study are the normalized grades.

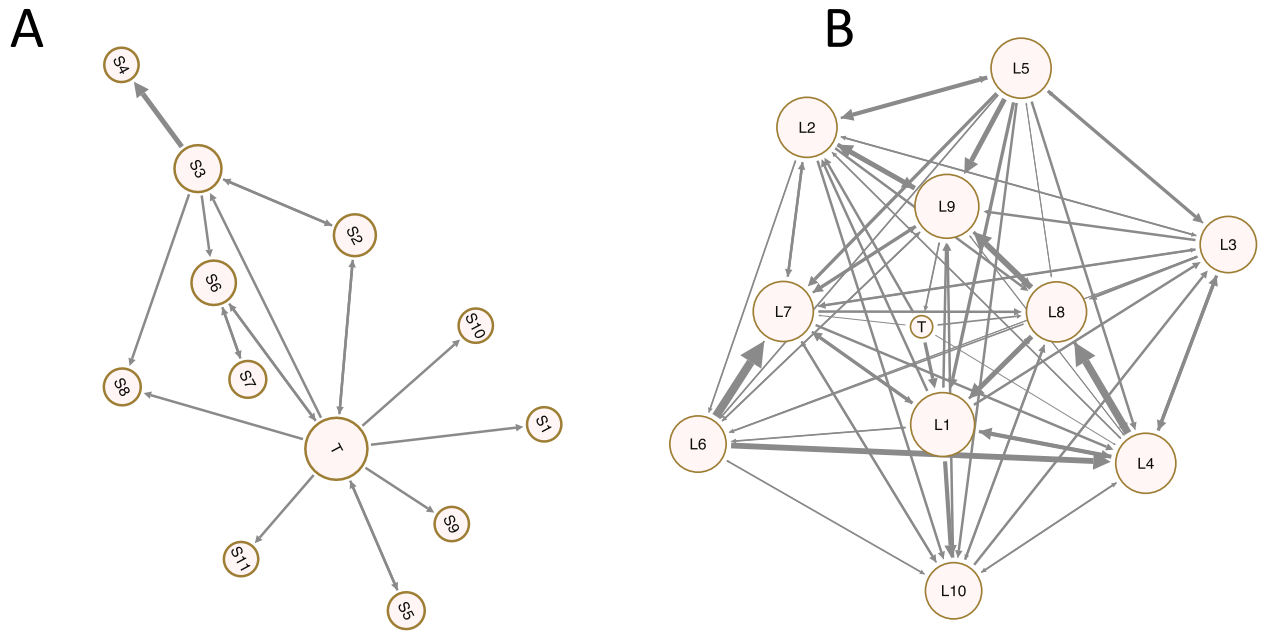

Fig. 1 two groups from the dataset, the left group **a** is relatively inactive, centralized around the teacher with few interactions among students. Group **b** (right) is relatively active, teacher is involved but not dominant. Legend: Each circle represents a student, the circle with the letter T represents the teacher and every line represents an interaction, the circle size is proportional to the degree centrality and the thickness of the lines is proportional to the frequency of interactions

Mean centrality measures of group members and the members' performance

The results of the group's average centrality measures (Table 3) confirm the previous findings reported in Table 2 that interactivity variables (average indegree and outdegree) were strongly and positively correlated with the group grade, and moderately with a change in group grade and fraction of improved students. Of notice is that the variance of outdegree as measured by standard deviation (indicating imbalance among participation) was strongly and negatively correlated with grade. The mean betweenness centrality of all groups was only positively significantly with the number of improved students; as for closeness centrality, it was consistently correlated with better group performance measures. In summary, interactivity is a good predictor of a group that will probably score high and helps more students perform better. These variables could also be used as indicators for group functioning.

Tutors and the group interactivity

Tutor's quantity of interactions (indegree or degree centralities) were not correlated with any of the group performance measures, except for the negative correlation of tutor outdegree and number of students who improved. Being close or reachable to most students (high closeness centrality) was positively correlated with the performance of the group. However, the betweenness

Table 2 Correlation between performance measures and SNA parameters of the group networks

Group variables	Grade		Difference in grade		Fraction of improved students	
	r	*p*	*r*	*p*	*r*	*p*
Number of students	−0.296	0.022	− 0.215	0.1	0.183	0.163
Edge count	0.506	< 0.001	0.478	< 0.001	0.557	< 0.001
Mean distance	−0.617	< 0.001	− 0.516	< 0.001	− 0.277	0.032
Centralization indegree	−0.267	0.04	−0.197	0.131	−0.068	0.604
Centralization outdegree	−0.681	< 0.001	−0.642	< 0.001	− 0.548	< 0.001
Centralization Betweenness	−0.56	< 0.001	− 0.489	< 0.001	−0.341	0.008
Centralization Closeness	−0.548	< 0.001	−0.537	< 0.001	− 0.437	< 0.001
Transitivity	0.665	< 0.001	0.576	< 0.001	0.511	< 0.001
Reciprocity	0.628	< 0.001	0.579	< 0.001	0.463	< 0.001

Table 3 Correlation between performance measures and SNA variables of the group members

SNA variables	Grade		Difference in grade		Fraction of improved students	
	r	*p*	*r*	*p*	*r*	*p*
Mean indegree	0.609	< 0.001	0.552	< 0.001	0.564	< 0.001
Mean outdegree	0.609	< 0.001	0.552	< 0.001	0.564	< 0.001
SD[a] indegree	0.113	0.391	0.156	0.235	0.322	0.012
SD outdegree	−0.625	< 0.001	−0.585	< 0.001	− 0.294	0.023
Median in degree	0.635	< 0.001	0.574	< 0.001	0.563	< 0.001
Median out degree	0.648	< 0.001	0.593	< 0.001	0.563	< 0.001
Mean betweenness centrality	−0.112	0.392	−0.034	0.795	0.272	0.035
Mean closeness in centrality	0.625	< 0.001	0.633	< 0.001	0.448	< 0.001
Mean closeness out centrality	0.554	< 0.001	0.58	< 0.001	0.416	0.001

[a]SD standard deviation

centrality of the tutors was negatively correlated with group performance measures. In the same vein the hubness score of the tutors was negatively correlated with the three performance measures. That is, students' performance was negatively correlated when tutors were more central in the interactions. Tutors usually try to stimulate groups that are not active, and their activity is a sign of a dysfunction not a cause per se. We see these results as a sign of difficulty scaffolding online groups. Table 4 includes all the statistics in details.

Using PBL interactivity variables of the group to predict group performance

A Stepwise multiple linear regression test was performed using the interaction variables of the three elements of the PBL process (the student, the tutor and the group) to predict group grade (dependent variable) with 60 observations. A significant equation was found, $F(4, 55) = 49.1$, $p < 0.01$, with an R2 of 0.76. The estimate of the constant term was 2.394 with a standard error of 0.492. The explanatory variables that accounted for the variance in groups' grades according to the last regression model were the Tutor Eigen centrality, the user count, and the centralization outdegree which were all statistically significant and negative. However, reciprocity in the group was a positive predictor of group improvement. In summary, a group where the tutor is connected to the less interactive students, with lower count of enrolled students, and a better distribution of interactions that are reciprocated is expected to perform better. Table 5 has the results of the regression model. The model did not violate collinearity statistics (Variance inflation factor). A 10-fold cross validation was performed to validate the model, the MSE was 0.144, the RMSE was 0.379, the MAE was 0.303 and the R2 was 0.733.

Discussion

In terms of group interactivity, the results of the study revealed structural patterns and group dynamics in PBL settings and the implications that they had on group performance. When taking a closer look at the network properties and performance, the analysis revealed that well-performing groups had more interactivity among the students. The interaction was also more equally distributed, indicating that the more active the students were replying to each other's contributions, the better the learning outcomes were likely to be.

The results of the study also showed that the performance of the group clearly suffered if the interaction was disproportionately concentrated or dominated by a few participants. This implies that when one or more dominant members inhibit the participation of others, it may

Table 4 correlation between tutor centrality measures and performance measures

	Grade		Difference in grade		Fraction of improved students	
	r	p	r	p	r	p
InDegree	−0.060	0.669	−0.057	0.680	−0.171	0.216
Outdegree	−0.125	0.368	−0.203	0.141	−0.29	0.034
Closeness in	0.444	0.001	0.47	0.000	0.191	0.166
Closeness out	0.229	0.096	0.215	0.119	0.182	0.188
Betweenness	−0.451	0.001	−0.41	0.002	−0.264	0.054
Hubness score	−0.648	0.000	−0.598	0.000	−0.444	0.001

Table 5 Stepwise regression variables for predicting group grades using interaction variables

	Standardized Coefficients	
	Beta	Sig.
(Constant)		0.00
Tutor Eigen Centrality	−0.398	< 0.000
User count	−0.354	< 0.000
Reciprocity	0.204	0.013
Centralization outdegree	−0.255	0.014

be a sign of a non-collaborative group that may not perform as expected. What is more, the analysis revealed that also the group size correlated with negative students' performance. It may indicate that in a large group, equal participation and contribution in collaborative efforts is difficult to achieve.

What is more, students' active participation, taking leader roles to foster peer collaboration was also evidenced to be more important than the tutor. Being close or reachable to most students (high closeness centrality) was positively correlated with performance of the group, while the tutor's quantity of interactions was not correlated with the group's performance variables. Additionally, the role of the tutor in information exchange by being a moderator (bridging the unconnected students), or a hub who leads the interactions, was significantly negatively correlated to the performance of the group. This means that when the tutor becomes dominating, it has a negative correlation with group performance, or be a sign of the tutor trying to help engage students by taking over the leader role.

Taken together, the results of this study indicate that active and reciprocal interactions between the students is particularly an important sign for successful group work in PBL settings. Active communication and equally distributed interaction may indicate that the group has found common ground that has been evidenced essential for collaborative learning [14, 19]. This finding is in line with earlier research in terms of advances of collaborative learning for individual learning suggesting that when learners collaborate, they generate strategies and problem representations that are unlikely to occur in individual learning [48] . Despite the effectiveness of collaborative learning, the group dynamics do not always function as expected [48], and thus, there is evident need for methodologies and tools that could help PBL groups to regulate their learning and joint work.

Methodologically, the present study sets an example of using SNA as a learning analytics tool for demonstrating network structures and group dynamics that predict the student performance and the factors that would help a group function. While previous studies have identified a number of variables which structures and influence the effectiveness of PBL [25, 49, 50], the current study takes one step further by showing how interactivity variables of PBL elements correlate with group performance with a large sample size. Although the absence of content analysis is a limitation of this study, the unique contributions of SNA is that it provides tools for automated analysis of large volume of interactions. Clearly, methodological progress made in automated content analysis will advance future research on PBL, however, it is still in the early stages.

Understanding of student interaction and participation also provides important information for adjusting tutor facilitation and course design in general. In practice, if analysis such as SNA would be further extended for temporal network analysis, such an analytical approach could be harnessed for educational contexts, so that, for example, instructors or tutors could immediately find out what types of interactions occur between the collaborating groups and then intervene if needed. Furthermore, this study has shown how certain quantitative interaction variables could be operationalized for supporting students to co-regulate their collaborative work. Such a tool could, for example, prompt PBL groups to increase awareness of unequal distribution of interactivity or low reciprocity, and thus, promote their metacognitive awareness. In similar vein, teachers could also use these insights for targeted intervention, and use the tool to evaluate the effects of the intervention for further adjustment and improvement [31]. Accordingly, there is a need to develop not only learning environments that support collaboration, but also advanced automated methods to capture group interactions [51]. At this moment, much of the research is going in that direction, but we are not there yet [52]. Therefore, we think that future research could capitalize on these findings and try to build tools that automate the analysis and reporting of students' interactions, and test methods for timely support based on these insights.

Conclusions

The findings of this study have demonstrated that quantitative accurate estimation of the role of students, tutors and the groups is feasible, easy to implement and notably useful. Variables reflecting the quantity of interactions, equal participation, inclusion of all group members, reciprocity and group cohesion were the predictors of a functioning group. Using these variables, social network analysis could be used to monitor and co-regulate online PBL groups, and potentially support the groups to function. The study has also demonstrated the possibilities and potentials of SNA techniques in PBL using a large sample of students and interactions, that could be used as a basis for automatic monitoring.

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Authors' contributions
MS, JN has contributed to the idea conceptualization, research design, and planning. MS has performed data collection and analysis. MS, JN, HV, JM have contributed to manuscript writing and revision and reporting of results and methods. The authors read and approved the final manuscript.

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Availability of data and materials
The data contains students' grades and private information and thus can be obtained through an application to the college ethical committee with appropriate procedure.

Ethics approval and consent to participate
The study protocol, consent documents and the consent procedure were approved by the Qassim Research Ethics Committee and issued a written approval of the study and a consent to publish. An online privacy policy that details possible use of data for research and user protection guarantees was signed online by all participants (reviewed by the ethical committee).
All personal data in this study were anonymized, and personal information was removed. It is also important to mention that all students were enrolled in the course and were able to complete it regardless of signing the agreement and were able to opt-out of participation in this research. The researchers did not participate in teaching, grading or organizing any of the courses in this study. The data are available from the authors upon a reasonable request and an ethical approval of the Qassim regional committee.

Consent for publication
The authors have obtained a consent to report the research report within the ethical approval from the college ethics research center.

Competing interests
The authors declare that they have no competing interests.

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