An Overview of Assessment of Competences based on publications in journals

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Abstract

Competences assessment transcends disciplinary areas and its research has increased worldwide. However, research in competence assessment in the engineering universe is something relatively new, concerning other disciplinary areas such as medicine and education. Understanding the state of art in areas where studies on competence assessment are more developed is an important step for transferring that knowledge to Engineering. This article aims to analyze the competences assessment state of art and to understand the actors involved in assessment methods (who is the assessor and who is being assessed), when and how the assessment process occurs, in medicine context, education, and engineering areas. The chosen approach was to carry out a literature review study based on a search using the Elsevier Scopus indexing service, in the timeframe 2000 to 2019. Using the search-terms "competences evaluation", "competencies evaluation", "competencies assessment" or "competences assessment", applied to title, abstract and keywords, was possible to identify 1,984 periodical documents, which 1,563 documents were of interest to the study, and related to Medicine, Education or Engineering areas. As a selection factor, the ten (10) most cited articles in each area were analyzed. Based on the study, the authors concluded the methods of assessing competences in medicine and education field may be used to support the Engineering area to develop reliable and valid methods for assessing competences. Besides, it was possible to identify that engineering competence assessment methods presented a focused computers simulators use. However, for medicine and education, the methods focus was evidenced in Objective Structured Clinical Examinations (OSCEs), based on scenarios.

Keywords: Competences Assessment; Competences Assessment Methods; Assessment of Engineering Competences.

1 Introduction

The culture of competence assessment arose from growing criticism of traditional testing; methods related to the unrealistic nature of tests. As a consequence, there was a "loss of faith" as valid learning measures (McDowell, 1995). The culture of competence assessment started to arise when US schools were held responsible for their educational outcomes. As a consequence, they began to realize most educational outcomes could not be assessed by paper and pencil tests (Stiggins, 1991).

This way, competence assessment can offer too much to education and training, promoting learning, evaluating progress, helping to determine curriculum effectiveness and training program (Kaslow et al., 2009). Besides, it makes possible to use assessment to guide and assess students development improving the instruction quality. In the state of art, competence definition is varied term, do not present a single definition. This study, define competence as characteristics, knowledge, skills, experience, and values that an individual needs to perform successfully in an academic or professional context (Achcaoucaou et al., 2014).

As learning and instruction are increasingly based on competences, there is a growing demand for assessment methods to determine competence (Baartman, Bastiaens, Kirschner, & van der Vleuten, 2007). However, methods for assessing professional/students competences can vary significantly. Research into assessment methods based on real or problem-oriented scenarios grows each year and demands logic/reasoning/argument competences, rather than simply remembering the facts (M. Govaerts, Van der Vleuten, Schuwirth, & Muijtjens, 2007; Kennedy, Regehr, Baker, & Lingard, 2008; Ornellas, Falkner, & Stålbrandt, 2019; Redfern, Norman, Caiman, Watson, & Murrells, 2002; Sharpless & Barber, 2009; Van Der Vleuten & Schuwirth, 2005). As well, technological advances have allowed the creation of a diverse range of simulators that can facilitate learning and assessment in different areas (Morgan & Cleave-Hogg, 2002; Scalese, Obeso, & Issenberg, 2008; Vedula, Ishii, & Hager, 2017; Ziv, Small, & Wolpe, 2000).

Although efforts to define and measure competences have been grown over the time. It is happening in recent years where a higher number of notable initiatives are being developed. Medicine and education have become reference areas in competences assessment. In this sense, this study aims to analyze the competences assessment state of art and to understand the actors involved in assessment methods (who is the assessor and who is being assessed), when and how the assessment process occurs in medicine, education, and engineering areas context.

2 Methodology

Considering the objective defined for this study and the lack of similar studies in engineering, an exploratory bibliographic research approach was chosen. This approach is intended to provide a first-hand information for competence assessment analysis in engineering, which allows to create conditions for future in-depth studies. The collection and treatment of data research were based on the following steps performed in the Scopus database, on March 07, 2020:

i) Browse for database with the search term (using double quotes) "competences evaluation", "competencies evaluation", "competencies assessment" or "competences assessment": 2,832 results.

ii) Select articles published in journals: 2,247 results.

iii) Select articles between the years 2000 to 2019: 1,984 results.

iv) Limit the results of interest areas (Medicine, Education, and Engineering): 1,563 results, 79% of the total.

v) Extract and analyze the ten (10) most cited papers in each subject area: 30 results.

vi) Exclude articles that did not fall within the research scope: 29 articles for analysis.

Table 1 shows the ten (10) most cited articles in each subject area, as well as the number of citations, according to the Scopus database.

Table 1. Analyzed papers

Medicine			Education			Enginnering		
Num	**Author**	**Citations**	**Num**	**Author**	**Citations**	**Num**	**Author**	**Citations**
1	Van der Vleuten & Schuwirth, 2005	581	**11**	Van der Vleuten & Schuwirth, 2005	581	**21**	Succar, Sher & Williams, 2013	93
2	Yule, Flin, Paterson-Brown & Maran, 2006	419	**12**	Kaslow et al., 2009	172	**22**	Amiri, Zandieh, Soltani & Vahdani, 2009	46
3	Dunn et al., 2006	280	**13**	Govaerts et al., 2007	156	**23**	Plebankiewicz, 2010	46
4	Scalese, Obeso & Issenberg, 2008	239	**14**	Ziv, Small & Wolpe, 2000	154	**24**	Rouse, 2011	31
5	Landon et al., 2009	218	**15**	Baartman, Bastiaens, Kirschner, & Van Der Vleuten, 2007	114	**25**	Berio & Harzallah, 2007	31
6	Norman et al., 2002	106	**16**	Redfern, Norman, Caiman, Watson, & Murrells, 2002	107	**26**	Vedula, Ishii & Hager, 2017	29
7	Sturman, 2005	99	**17**	Norman et al., 2002	103	**27**	Augustin, Hockemeyer, Kickmeier-Rust, & Albert, 2011	25
8	Govaerts et al., 2011	96	**18**	Govaerts et al., 2011	101	**28**	Bohlouli et al., 2017	24
9	Sharpless & Barber, 2009	81	**19**	Yanhua & Watson, 2011	99	**29**	Arditi & Balci, 2009	18
10	Morgan & Cleave-Hogg, 2002	78	**20**	Kennedy, Regehr, Baker & Lingard, 2008	89	**30**	Achcaoucaou et al., 2014	15

The search resulted in 1,563 publications. Table 2 shows the publications of the last 20 years (2000 to 2019) in the disciplinary areas. Besides, to understand the origin of studies on assessment of competences, the first research in medicine area, took place in 1967 in the United States. The assessment of competences for education appeared in 1974, also in the United States. Then, after 19 years, in England, Engineering began to invest and concern about studies on the subject.

the analysis presented in table 2 shows a variation in medicine and education publications. In education it is possible to see that 59 publications were developed (2015). However, on previous years this number decreased, increasing again just in 2019. In 2017, a 64% of growth in competence assessment in medicine could be

observed. It is important to notice that in 2019 researches related to engineering area were developed with a significant increase related to 2018.

Table 2. Number of publications by subject area

#	Medicine	Education	Engineering	#	Medicine	Education	Engineering
2019	97	77	**20**	**2009**	47	27	4
2018	98	53	7	**2008**	42	18	1
2017	**100**	47	9	**2007**	50	32	2
2016	64	49	3	**2006**	39	17	0
2015	57	**59**	5	**2005**	25	15	3
2014	70	44	5	**2004**	33	9	0
2013	52	46	7	**2003**	29	11	1
2012	57	32	5	**2002**	22	13	0
2011	48	37	6	**2001**	12	9	1
2010	32	24	4	**2000**	16	9	0

3 Bibliometric analysis

Initially, a general analysis on this study subject is considered and then the increasing publications number is presented, as well as countries, higher education institutions, authors, and journals with greater attention to the theme.

3.1 Top authors on competences assessment

The research results were analyzed considering the number of publications by the authors. In medicine, Appelbaum, P. S. is the author with the largest number of publications, resulting in twenty-three (23) appearances. Appelbaum has an affiliation at Columbia University Irving Medical Center, Department of Psychiatry (United States). In education, Baartman, L. K. J. developed eight (8) articles linked to the Open University of the Netherlands, Welten Institute, Heerlen, (Netherlands). Finally, in engineering, Jennings, M. is the author with the largest number of publications, all from the University of Aberdeen (United Kingdom) with three (3) studies.

3.2 Top 5 higher education institutions that publish on Competences Assessment

The research results in Scopus database for the whole world presented more than 200 higher education institutions which has publications on the topic. The University of Toronto is a reference in publications numbers for medicine area, as well as the Maastricht University for Education. In Engineering, the numbers in Educational Institutions show similarities, however, the University of Aberdeen has developed 3 papers. Due to the reduced number of publications per institution in engineering, it was decided to summarize only the areas of medicine and education, see Table 3.

Table 3. Educational Institutions with the highest number of publications

#	Medicine	Num	Education	Num
1	University of Toronto	32	Maastricht University	14
2	University of California	24	Universitat Autònoma de Barcelona	11
3	Harvard Medical School	24	Universitat de Barcelona	8
4	University of Pennsylvania	22	University of Massachusetts Medical School	7
5	University of Washington	22	Utrecht University, Universidad Complutense de Madrid	7

3.3 Journals with the higher number of papers published between 2000 and 2019

The research presents the main journals that publish about the topics described in Table 4. An in-depth view of these sources allowed the studies identification in medicine regarding competences assessment directed to journals focusing on Surgical Education, Psychiatry, Endoscopic Surgery, Emergency and geriatric psychiatry.

In education, the mainly results include journals related to studies on assessment of competences for nursing, which may, in fact, overlap education and medicine studies. Regarding it, they can be simultaneously found on

Scopus database, both in medical and education journals. In engineering, the publications sources are diverse, however, two (2) of the identified sources are related to Engineering Education. They are: International Journal of Engineering Education and European Journal of Engineering Education.

Table 4. Journals with the higher number of papers

#	Journals	Num
1	Nurse Education Today	25
2	Academic Medicine	24
3	Training and Education in Professional Psychology	19
4	Journal of Continuing Education in Nursing	15
5	Journal of Dental Education, Nurse Education in Practice	14

3.4 Top 10 Countries that published on Competences Assessment

The research resulted in 1,563 publications and presented the 15 countries that most published on competences assessment. In table 5 is possible to see the top 15 countries for each area. The United States is the country with the largest number of publications for medicine and education. Nevertheless, China is the country with the highest number of publications in Engineering.

Table 5. Top 10 countries with the highest number of publications

#	Medicine	Num	#	Education	Num	#	Engineering	Num
1	**United States**	**547**	**1**	**United States**	**264**	**1**	**China**	**14**
2	United Kingdom	129	2	Espanha	68	2	United States	12
3	Canada	93	3	United Kingdom	48	3	Spain	8
4	Australia	64	4	Germany	40	4	United Kingdom	5
5	Netherlands	41	5	Canada	38	5	Australia	3
6	Germany	37	6	Netherlands	35	6	Malaysia	3
7	Italy	32	7	Australia	34	7	Philippines	3
8	Spain	32	8	Russia	12	8	Chile, Germany, India, Indonesia, Iran, Italy, Lithuania, Poland, Saudi Arabia, South Korea, Switzerland, Thailand	2
9	India	20	9	China	8			
10	France	19	10	Ireland, Malaysia, New Zealand, Norway, Thailand	7			

4 Competences assessment methods

The literature on competences assessment can be analyzed from different perspectives. The assessment of competences in the engineering universe is something relatively new compared to other disciplinary areas such as medicine and education. Understanding the state of the art in areas where studies in competences assessment are deeply developed, this research becomes a relevant tool in order to help to develop methods for assessing competences in Engineering context.

Considering this context, 28 (twenty-eight) competences assessment methods were analyzed, using guiding questions as parameters for analysis. Thus, questions were selected as: Who is the competences assessor? Who is being assessed? At what time the competences assessment is performed? How is the competences assessment performed? Such questions were analyzed from the perspective of competence assessment methods, as Figure 1 presents. Initially, the definition of the term "competences" is presented from different perspectives.

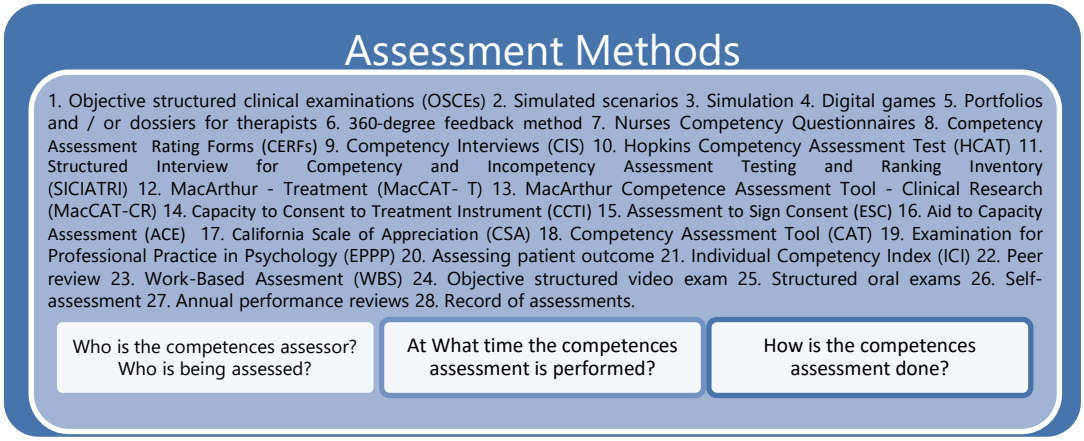

Figure 1. Analysis of Competences Assessment Methods

Neither all assessment methods were analyzed in the 3 (three) guiding questions. As an example, in MacArthur Competence Assessment Tool, the patient is assessed according to his competences to consent with the treatment defined by the professionals. In this study, the method analysis will not be performed related to the actors involved in the process. On the other hand, its of evaluation model was considered for analysis.

4.1 Different definitions of competence

In the analysis of the assessment methods, it was possible to identify that the evaluation process developed for students, doctors, psychologists and professionals are exclusively to analyze their skills, and not experiences or ability. Table 6 presents different definitions for the term competence, according to authors under analysis.

Table 6. Definition of the term Competences

Author(s)	Definition of Competences	
Van Der Vleuten and Schuwirth (2005)	It is the ability to deal with a complex professional task, integrating relevant cognitive, psychomotor and affective skills.	MEDICINE
Sturman (2005)	It refers to a judgment about whether a person is able to provide informed consent.	
Sharpless and Barber (2009)	The status or quality of being adequate or well qualified, demonstrates ability or may have a legal definition (that is, being legally qualified to take some action).	
Redfern et al. (2002)	Ability to operate in the real world, whatever the conditions.	EDUCATION
Baartman et al. (2007)	It consists of connected knowledge, skills and attitudes that can be used to properly solve a problem.	
Succar, Sher, and Williams (2013)	It refers to an individual's ability to perform a specific task or deliver a measurable result.	ENGINEERING
Rouse (2011)	Sufficient knowledge, capacity and experience to allow the successful completion of a task / initiative.	
Augustin, Hockemeyer, Kickmeier-Rust, and Albert (2011)	Method as the student develops the digital game solutions.	
Bohlouli et al. (2017)	Knowledge, experience and skills that people need to perform their duties.	
Achcaoucaou et al. (2014)	Characteristics, knowledge, skills, experience and values that an individual needs to perform successfully in an academic or professional context.	

4.2 Who is the competences assessor? Who is being assessed?

The Objective Structured Clinical Examinations (OSCEs), consist of several clinical meetings (called stations), typically with trained actors, playing the role of a client/patient presenting one or more symptoms. Thus, the assessment method is carried out by specialists, doctors, psychologists or teachers to assess students and/or health professionals (Kaslow et al., 2009; Redfern et al., 2002; Van Der Vleuten & Schuwirth, 2005; Yanhua & Watson, 2011).

Perception Questionnaires are the standard competence assessment methods for nurses and psychologists. A popular assessment method in psychology is the so-called Competency Assessment Rating Forms (CERF) or perception questionnaire, and in the research by Kaslow et al. (2009) the assessor actors are characterized by

specialists in the field. In this sense, the competence assessment method, entitled Nursing Competences Questionnaire, provides a basis to develop a national method for assessing clinical competences (minimum standards). The method could be used by nurses (assessed), nurse professors and professionals (as assessors) (Norman, Watson, Murrells, Calman, & Redfern, 2002).

In addition, the requirement for all psychologists seeking licensure in the USA, is the Examination for Professional Practice in Psychology (EPPP). Though, in psychology area, another popular assessment method is the pre and post-therapy assessment, being patients in treatment (assessed) and psychologists (the assessors) (Sharpless & Barber, 2009). The person assessing competences is called "assessor" and the person being assessed is the "assessed".

The studies by Kennedy et al. (2008), Redfern et al. (2002), Sharpless and Barber (2009) and Van Der Vleuten and Schuwirth (2005), involve the construction of situations that resemble real practice scenarios. The assessment modes, such practical scenarios, can occur from the perspective of specialists, doctors, psychologists, teachers, students or health professionals.

Students and/or health professionals are assessed by the field specialists through certain performance assessment methods such as: objective structured video exam assessment methods, structured oral exams, self-assessment, annual performance reviews and assessment records (Kaslow et al., 2009).

Simulation-based education allows trainees to improve their competences in a risk-free environment. In this type of assessment method, the simulation takes place through specialists performing the assessment process (as assessors), and students and/professionals being assessed (Berio & Harzallah, 2007; Morgan & Cleave-Hogg, 2002; Scalese et al., 2008; Vedula et al., 2017; Ziv et al., 2000).

In digital games assessment method, the mathematical structure relates the problem solution of student's behavior. In digital games, the student's behavior (in game context) is evaluated related to their identified and absent competences (Augustin et al., 2011). The portfolios assessment methods and/or dossiers of therapists allow the information collection and compilation on the evidence of the patient performance (assessed) and psychologists, doctors or specialists as assessors (Kaslow et al., 2009; Sharpless & Barber, 2009; Van Der Vleuten & Schuwirth, 2005). The 360-degree feedback method contributes to the development of competences. This method allows supervisor, co-worker, teacher, specialist, doctors or psychologists be responsible for the assessment process, which can be developed for students and/or health professionals (assessed) (Bohlouli et al., 2017; Kaslow et al., 2009; Sharpless & Barber, 2009; Van Der Vleuten & Schuwirth, 2005).

In the Peer Review method, proposed by Van Der Vleuten and Schuwirth (2005) students and professionals from any area are assessed by specialists. The Work-Based Assessment (WBS) method, aims to build impressions and perform judgments about student's performance (assessed), for this method, teachers and specialists can be characterized as assessors (M. Govaerts, Schuwirth, van der Vleuten, & Muijtjens, 2011). The authors Succar et al. (2013) developed a method for assessing the competences of students and professionals (assessed), entitled as the Individual Skills Index (ICI), which can be assessor by specialists. In order to assessment Polish civil construction contractors (assessed), the assessment method in an interview format was sent to clients (assessors) providing a contractors prequalification (Plebankiewicz, 2010).

4.3 At What time the competences assessment is performed?

The research results were also analyzed related to the moment where the assessment process takes place. The results present the assessment of competences being applied in different times as a qualification exam, interview, or even without any specific context, which can occur at any time.

Assessment methods such as Objective Structured Clinical Examinations (OSCEs), simulation, digital games, nurses' competence questionnaires, Examination for Professional Practice in Psychology (EPPP), Work-Based Assessment (WBS), objective structured video exam, exams structured oral and annual performance reviews, are methods that typically occur in an exam process . Furthermore, competence assessment methods that consist in scenarios can occur in an interview process, as a qualification exam.

On the other hand, examples of methods which the assessment process can occurs at any time are 360-degree feedback method, Competency Assessment Rating Forms (CERFs), MacArthur Competence Assessment Tool,

Peer review, Self-assessment, and Assessment record (Bohlouli et al., 2017; Dunn, Nowrangi, Palmer, Jeste, & Saks, 2006; Kaslow et al., 2009; Sharpless & Barber, 2009; Succar et al., 2013; Van Der Vleuten & Schuwirth, 2005). In the method of assessment through Portfolios and/or dossiers of therapists, patients undergoing treatment are assessed by psychologists or specialists as well.

4.4 How is the competences assessment done?

The results present different forms in assessment process, which are analyze how the assessment process is carried out. It can be done from questionnaires, forms, interviews, use of simulation, documents, protocols, self-report to simulated scenarios with real practice.

Perception questionnaires and forms are methods identified as support and in some cases other are used to complete the assessment (Arditi & Balci, 2009; Norman et al., 2002; Sturman, 2005; Yule, Flin, Paterson-Brown, & Maran, 2006). In the Competency Assessment Rating Forms (CERFs), the the assessment is done using semi-structured form, through a list of indicators with personal and practical competences (Kaslow et al., 2009; Yule et al., 2006). Similarly, Nurses' Competence Questionnaires method are organized into 78 (seventy-eight) items divided into eight constructs, namely: leadership, professional development, assessment, planning, intervention, cognitive ability, social participation and ego strength. The evaluated subjects classify their own competence in each item using a performance frequency scale of 4 (four) points (never forever) (Norman et al., 2002).

The assessment using the Hopkins Competency Assessment Test (HCAT) method is performes through questions of true / false format and sentence completion, with scores ranging from 0 to 10 (higher scores indicating greater competence). In addition, there are methods that use the form of structured and semi-structured interviews to assess competences (Berio & Harzallah, 2007; Sturman, 2005). Therefore, the interviews are structured in items, and each item is classified on a Likert scale. Still, to complement the assessment, self-report is another very common possibility for assessing competences (Sturman, 2005).

The method structure possibilities can be identified in exam format. In the Examination for Professional Practice in Psychology (EPPP), a test with multiple choices for the assessment process is used. Oral tests are used for structured oral exams and the structured video exam competences assessment method uses real practice in video format for assessment (Kaslow et al., 2009; Sharpless & Barber, 2009). In the Objective Structured Clinical Examinations (OSCEs), Work-Based Assessment (WBS) and the simulated scenario assessment method, are simulated, and use rubrics as tools to assess performance (Bohlouli et al., 2017; Kaslow et al., 2009; Sharpless & Barber, 2009; Van Der Vleuten & Schuwirth, 2005).

Nevertheless, the simulation can be used as a way to assess competences (Augustin et al. 2011) and also an online software (Berio & Harzallah, 2007; Succar et al., 2013). Furthermore, in some of the competences assessment methods, documents and/or multiple choice and/or videos are used as an assessing form (Kaslow et al., 2009; Sharpless & Barber, 2009; Van Der Vleuten & Schuwirth, 2005). Finally, real scenarios and practices are found as a assessing competences mode (Kaslow et al., 2009).

Assessment of people's competences are often found in literature, on the other hand, studies that evaluate the most important competences for organizations are less viewed. The Amiri, Zandieh, Soltani, and Vahdani (2009) study used a quantitative analysis to identify aspects and attributes of competence, using the AHP Adaptive approach as an assessment framework. In the peer review method, a check sheet is used to support the assessment process; to assess the performance and compare it with a certain level of competence (pre-established by the assessors) (Kaslow et al., 2009; Van Der Vleuten & Schuwirth, 2005).

Finally, a check sheet that includes five (5) levels, is described as the method of assessment used in the Individual Competency Index (ICI) specific area or topic; level 1 (basic) denotes an understanding of the fundamentals and some initial practical application; level 2 (intermediate) denotes a solid conceptual understanding and some practical application; level 3 (advanced) denotes significant conceptual knowledge and practical experience in executing a competence according to a high and consistent standard; and level 4 (specialist) indicates extensive knowledge (Succar et al., 2013).

5 Conclusion

This study aims to analyze the competences assessment state of art and to understand the actors involved in assessment methods (who is the assessor and who is being assessed), when and how the assessment process occurs in medicine, education, and engineering areas context.

The importance of assessing competences in higher education institutions is undeniable. This fact reflects the growing number of studies in different subject areas, taking medicine and education as reference. Engineering seeks through seminal studies, the design and development of methods for assessing competences that are reliable and valid for the engineering context. Thus, the understanding of the state of the art has become an important result, even if initially, to develop methods for assessing competences for engineering.

Some of the main results of the presented study can be summarized using the 3 (three) guiding questions. The assessors actors involved in the competence assessment processes were doctors, psychologists, teachers and professionals; the actors assessed are defined as students and professionals. For the assessment moment , the application takes place at different times, which may be in a qualification exam, interview or even, without any specific context, occurring any time. As the assessment is done, there are perception questionnaires, forms, interviews (structured and semi-structured), simulation use, documents, protocols, self-report and simulated scenarios with real practice. In addition, methods such as a check sheet, rubrics, grids, are used as a guide and, in some cases, scales are used to determine the competence level as well.

Finally, the authors conclude that the methods of evaluating competences medicine and education field can serve as support tools and assist Engineering to develop reliable and valid methods for assessing competences. Moreover, it was possible to identify that the engineering competence assessment methods presented that there is a strong focus on the use of simulators, through computers, in their assessments. However, for medicine and education, was evident the importance of the use of scenarios methods for assessment of competences.

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