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Longitudinal variation of correlations between different components of assessment within a medical school

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Abstract

Background An assessment program should be inclusive and ensure that the various components of medical knowledge, clinical skills, and professionalism are assessed. The level and the variation over time in the strength of the correlation between these components of assessment is still a matter of study. Based on the meaningful learning theory and the integrated learning theory, we hypothesize that these components increase their connections during the medical school course.

Methods This is a retrospective cohort study that analyzed data collected for a 10-year period in one medical school. We included students from the 3rd to 6th year of medical school from 2011 to 2021. Three assessment components were addressed: Knowledge, Clinical Skills, and Professionalism. For data analysis, Pearson correlation coefficients (R) and R^2 were calculated to study the correlation between variables and a z-test on Fisher's r-to-z was used to determine the differences between correlation coefficients.

Results 949 medical students were included in the study. The correlation between Clinical Skills and Professionalism showed a medium to strong association (Pearson's R ranging from 0.485 to 0.734), while the correlation between Knowledge and Professionalism was weaker but exhibited a steady evolution with Pearson's R fluctuating between 0.075 and 0.218. The Knowledge and Clinical Skills correlation became statistically significant from 2013 onwards and peaking at Pearson's R of 0.440 for the cohort spanning 2016–2019. We also revealed a strengthening of correlations between Professionalism and Clinical Skills from the beginning to the end of clinical training, but not with the knowledge component.

Conclusions This analysis contributes to our understanding of the dynamics of correlations of different assessment components within an institution and provides a framework for how they interact and influence each other.

Trial registration This study was not a clinical trial, but a retrospective observational study, without health care interventions. Nevertheless, we provide herein the number of the study as submitted to the Ethics committee – CEICVS 146/2021.

Keywords Longitudinal assessment, Assessment correlations, Meaningful learning theory, Integrative learning theory

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Background

Assessment within a medical school can involve a variety of components, including cognitive, clinical skills, and professionalism [20]. Knowledge assessment within a medical school typically involves evaluating students' knowledge and understanding of course material through exams and other forms of testing. This may include written exams, oral exams, or practical exams in which students demonstrate their skills and knowledge through simulations or other hands-on activities [25]. Skills assessment within a medical school typically evaluates students' ability to apply their knowledge and understanding in a clinical setting. This may involve evaluations of students' clinical skills during rotations or other supervised clinical experiences, as well as simulations and case-based learning activities [9, 19, 23]. Professionalism assessment within a medical school is concerned with evaluating students' behavior and attitudes as they relate to the ethical and professional standards of the medical profession [12]. This may include evaluations of students' communication skills, teamwork, and ability to work with patients and colleagues in a respectful and compassionate manner [2, 10]. Overall, this framework of assessment within a medical school aims to ensure that students are acquiring the knowledge, skills, and professionalism required to become competent and compassionate healthcare professionals.

It is assumed the existence of a relationship between knowledge and clinical skills (Sheets [26]; [14], Lurie and Mooney, [17]). In fact, previous studies have demonstrated high correlations between scores on performance-based tests and written exams and their potential predictive value [9, 14, 21, 28, 30]. It is common for the correlations between different assessment components to vary over time as students' knowledge and skills evolve and their focus shifts from one area to another (van der Vleuten and Swanson [31]). Interestingly, it was shown that clinical grades correlate with the expertise and professionalism domains [1, 8, 13] and predict subsequent knowledge and professionalism ratings ([32], Lurie and Mooney, [17]), suggesting that clinical skills performance reflects both cognitive and noncognitive domains. However, it is important to note that other studies failed to find a relationship between clinical grades and noncognitive performance measures [4–6].

With this starting point of previous works showing us several interactions amongst different types of knowledge and skills, a larger question emerges on the correlation between the different components that are assessed during medical school and how these correlations evolve during medical training. The meaningful learning theory, proposed by David Ausubel, states that the learner interprets, relates, and incorporates new information with existing knowledge and applies the new information to solve novel problems [3]. In a similar basis, the integrative learning theory proposes that students take ownership of their own learning, becoming critical inquiries who are able to make meaningful connections between different disciplines and utilize critical thinking to real-life problems [18]. Both this learning theories highlight that learning is a higher process that depends on the crossing of different types of knowledge and concepts, suggesting that students are able to use their own acquired information on one topic to build and develop another, even if these topics are of different nature (theoretical knowledge, clinical skills, professionalism). To further build on this question, we hypothesize that this integrated, meaningful, learning might be translated into the assessment results, which in turn should show the longitudinal growth in interconnections between the acquisition of knowledge, clinical skills and professionalism.

Understanding the longitudinal correlations between various assessment components in medical school is crucial for several reasons. First, it provides insights into how students integrate knowledge, clinical skills, and professionalism over time, reflecting the holistic development essential for competent healthcare professionals. By identifying patterns and shifts in these correlations, this study contributes to a deeper understanding of the educational process, highlighting areas that may need more focus or adjustment in the curriculum. The findings will enable educators and administrators to design more effective and targeted educational strategies, ensuring that assessments are not only comprehensive but also aligned.

To better understand these connections, using the data collected for more than one decade in the same medical school, we herein explore the longitudinal variation in correlations between different components of assessment, using a range of assessment methods to ensure that students are being adequately evaluated across all dimensions of their education.

Methods

Study design and context

A retrospective cohort study was set at the School of Medicine – University of Minho (EM-UM), with the approval of the Ethics Committee of the University of Minho (CEICVS-146/2021) (Supplementary Material). Participants were waived from informed consent due to the retrospective nature of the study by the Ethics Committee of the University of Minho. The Declaration of Helsinki and the Council of Europe's Convention on Human Rights were strictly followed. Data from this retrospective database was extracted in December 2021.

The EM-UM started its activity in 2001 with an assessment program that has been used for the past 20 years, with greater stability in the last 10 years. Overall, the program includes several assessment components with different goals and is divided into three major assessment components: theoretical knowledge, clinical skills, and professionalism.

Multiple scales and methodologies are used and repeated throughout the course, meaning that students of different years are evaluated with the same methodologies over time. This creates a valuable opportunity to understand better the relationship between the components of the assessment program.

Assessment methods

In this study, we included the four curricular units where the students' residencies took place in the Internal Medicine Departments to assure the assessment methodologies and the evaluators were similar.

To assess the three components previously described (Knowledge, Clinical Skills, and Professionalism), we collected data from the following assessment tools:

- *Assessment of theoretical knowledge*: written exams performed at the end of the clinical units with clinical vignettes in the format of Single Best Answer Questions.
- *Assessment of clinical skills*: Objective Structured Clinical Examination (OSCE) in a simulation context with several assessment scales including the Minho Communication Assessment Scale [11] and clinical checklist for the history taking and for physical examination, which are combined to calculate a final score for the OSCE, and a Clinical Competences Scale (CCompScale) of eight 9-point Likert scale questions assessed by the student's tutors in the hospital.
- *Assessment of professionalism:* a Professionalism Scale (ProfScale) of eight 9-point Likert scale questions assessed by the student's tutors in the hospital.

All of the assessment tools previously described, were transformed in a final score between 0 and 20.

The first of these curricular units takes place at the end of the 3rd year of medical school and focuses on semiology, general aspects of medical practice with special focus on internal medicine and clinical skills. The two following curricular units take place in the 4th and 5th year of medical school and include all the medical specialties covered by internal medicine (Cardiology, Gastroenterology, Pneumology, Hematology, Oncology, Nephrology, Dermatology, Infectious diseases, and Rheumatology). In the 6th year, the students have one final curricular unit with a nearly 2-month clerkship in internal medicine. At the end of the four of these curricular units, the students go through a written exam that covers all the topics discussed during each curricular unit. They are also assessed on their clinical skills, with an OSCE on their 3rd and 6th year and with a clinical competence scale applied by their tutors in the hospital residencies in all the clinical curricular units. Another tool used in all the curricular units is the Professionalism scale, also applied by the tutors in the hospital residencies.

The EM-UM kept an assessment program and faculty globally stable throughout the 10-year period, making us able to study the evolution of correlations between these instruments and assessment components.

Sample size

For this study, we collected the assessment data of students from the 3rd to the 6th year of the medical school from 2011 to 2021.

The inclusion criteria were: 1) to be a student from the 3rd to the 6th year of medical school and have attended the four curricular units sequentially.

The exclusion criteria were: 1) to have not completed the sequential curricular unit.

During the 10-year analysis, it was possible to study 8 cohorts of students longitudinally during their clinical course. It is estimated that about 140 students are enrolled in the first clinical unit in the 3rd year each year, which represents a total of approximately 1120 students over the 10 years.

Variables and statistical analysis

Regarding the three assessment components, we computed the following variables: Knowledge, Clinical Skills, and Professionalism. For the Knowledge component, we collected the results of the Written Exams from each student in each curricular unit, combining a total of 72 exams during the 10-year period. For the Clinical Skills component, we computed a variable representing the mean between the OSCE of the curricular units in the 3rd and 6th year and the CCompScale from each student in each curricular unit, including the CCompScale of the curricular units from the 3rd to the 6th year. The overall Clinical Skills variable derived from a total of 16 OSCE's and 32 CCompScale assessments. For the Professionalism component, we collected the results of the ProfScale from each student in each curricular unit. For the first analysis of the correlation between components, all the results of all the included students were included as one group, independently of the cohort of students. For the second analysis, we analyzed the variation of correlations between components over time. For this analysis, we included all the results of all the included students

Table 1 Correlation analysis between three components of assessment: Knowledge, Clinical Skills and Professionalism

Variable		Professionalism	Clinical Skills
1. Professionalism	Pearson's r	—	
	p-value	—	
2. Clinical Skills	Pearson's r	0.617	—
	p-value	< .001	—
3. Knowledge	Pearson's r	0.154	0.159
	p-value	< .001	< .001

divided in 8 cohorts by years of medical school attendance for each group.

Within the three components, different assessment methods were assessed: Written Exams, OSCE, ProfScale and CCompScale. For the final analysis of this work, we focused on the evolution of the correlations between these different methods of assessment between the 3rd to the 6th year.

To study the correlation between variables, we calculated the Pearson correlation coefficient (R) and the R^2. "R" values near -1 or 1 were considered perfect correlation; -0,95 or + 0,95 – strong correlation; -0,5 and + 0,5 values – medium correlation; -0,1 or + 0,1 – weak correlation; 0,0 – no correlation. Additionally, to study the statistical significance of the difference between the correlation coefficients for the comparison between the third and sixth years, we used a z-test on Fisher's r to z-transformed correlation coefficients for dependent variables [27]. Data was analyzed with JASP 0.16.2.0 and Quantpsy online calculator [15].

Results

Data were collected on the evaluation of 1154 students from the 3rd to 6th year medical school between 2011 and 2021. This number is slightly higher than estimated because the number of students entering medical school is not always stable over the years, leading to a surplus of 34 students. 205 students were excluded for two reasons: one was not having completed the curricular units in a sequential manner which happened in 113 cases; two was due to multiple missing values making it impossible to calculate the variables which happened in 92 cases. Thus, it was possible to analyze the data of 949 students.

Correlation between different assessment components

In this first part of this study, we searched for the correlations between the three main components of assessment. In Table 1 we present the correlations between these components over the 10 years cumulatively.

The longitudinal analysis showed statistically positive correlations between clinical skills and professionalism for all eight groups analyzed between 2011 and 2021 (Table 2). Interestingly, this correlation was medium to strong and was stable over the years, with a maximum Pearson R of 0,734 in the group 2012–2015 and a minimal Pearson R of 0,485 in the group 2013–2016 (Fig. 1).

As for the correlations between the knowledge and professionalism components, we found a positive correlation in all the groups except for the 2012–2015 group (Table 2). The correlation between these two components of assessment was weaker than that between clinical skills and professionalism, but it also displayed a stable evolution throughout time, with a maximum value Pearson R of 0,218 in the group 2011–2014 and a minimal Pearson R of 0,075 in the group 2012–2015 (Fig. 1).

Finally, for the correlations between the knowledge and clinical skills components, there was a positive correlation in all the groups starting after 2013 (Table 2). The correlation between these two components of assessment was also weaker than between clinical skills and professionalism; interestingly, data shows a clear progression in this correlation as there was no significant correlation in the first two groups, but over time it emerged a statistically positive correlation that reached a maximum value Pearson R of 0,440 in the group 2016–2019 (Fig. 1).

Analysis of the evolution during the clinical years of the correlation between different instruments of assessment

One crucial question addressed in the present study was whether there were significant variations of these correlations along the students' progress in their clinical

Table 2 Correlation coefficients between three assessment components: Knowledge, Clinical Skills and Professionalism, over 10 years, by cohorts

	2011–2014	2012–2015	2013–2016	2014–2017	2015–2018	2016–2019	2017–2020	2018–2021
Knowledge - Clinical Skills	-0.032	-0.055	0.187***	0.406***	0.190***	0.440***	0.253***	0.099*
Knowledge - Profissionalism	0.218***	0.075	0.148***	0.197***	0.158***	0.096*	0.204***	0.183***
Clinical Skills - Profissionalism	0.516***	0.734***	0.485***	0.673***	0.627***	0.631***	0.596***	0.694***

* $p < 05$

** $p < 01$

*** $p < 001$

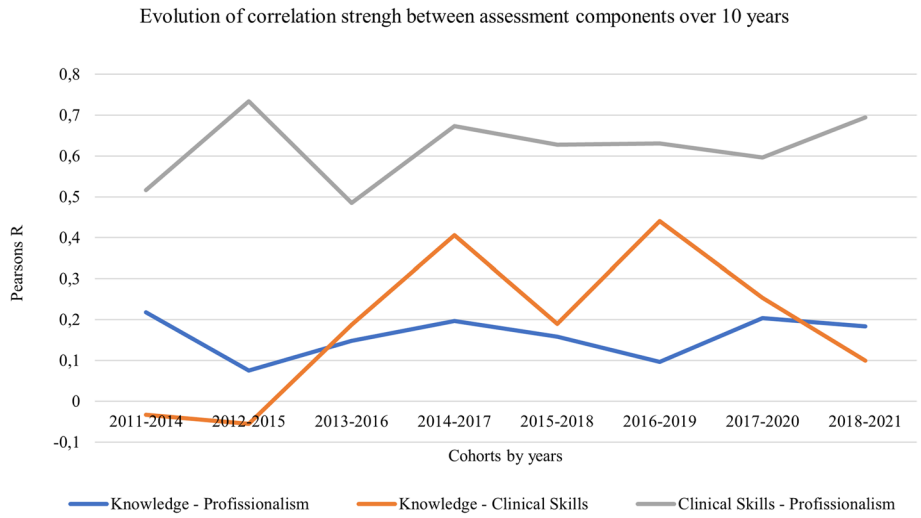

Fig. 1 Evolution of correlation strength between assessment components over 10 years

training. Figure 2 reveals that there was stability between the 3rd and 6th years regarding the correlations involving the Knowledge component. Interestingly, there was an increase in correlation between the beginning and the end of clinical training between Professionalism and Clinical Skills (from 0,572 to 0,687).

To further understand the reasons underlying the increase in correlations between the Clinical Skills component and the Professionalism components, we performed a separate analysis focusing on the instruments used to assess Clinical Skills: the OSCE and the CCompScale. As shown in Fig. 3, there is a marked increase in the correlation of the performance between the OSCE and the ProfScale ($z = 3.782$; $p = 0.00016$), the OSCE and the CCompScale ($z = 4.145$; $p < 0.0001$) and the ProfScale and the CCompScale ($z = 9.582$; $p < 0.0001$) from the beginning of the clinical training (3rd-year students) and its end (6th-year students). In contrast, there were no significant changes throughout the clinical training in the correlations involving the Written Exams. The correlation between the Written Exams and the ProfScale was previously presented in Fig. 2 (described as "Knowledge – Professionalism"), showing there were no significant differences between the 3rd and 6th years.

Discussion

In this study, we explored the overall correlations between different assessment components and instruments to better understand how these components are connected and how they evolve during pre-graduate medical training. First, we focused on the correlation and its evolution over time between three main components: Professionalism, Clinical Skills, and Knowledge. Afterward, we analyzed the evolution of the correlations of these components between the beginning and the end of clinical training.

As for the first aim of this study, it is important to mention that the strength of the correlation between different measures is relevant for the underlying construct being measured because it can provide insight into the degree to which the measures measure the same thing. If the correlations are strong, it may indicate that they are measuring a similar underlying construct; on the other hand, if the correlations are weak, it may indicate that they are measuring different constructs or that there is some other factor influencing the relationships between the measures. Moreover, it can help us to determine the reliability of the measures we are using. If the correlations between different measures are strong, it may indicate that the measures are reliable and that they are providing consistent results; in contrast, if the correlations between the measures are weak, it may indicate that the measures are not reliable and that the results we are getting may be inconsistent or unstable. These concepts can be particularly important in the context of evaluating the effectiveness of an intervention or educational program, as changes in the correlations between different measures may indicate changes in the underlying skills or abilities being targeted by the intervention.

In the first analysis of this study, we found a positive correlation among the three main components of assessment, which is in line with previous studies [7, 9, 14, 17, 24, 29]. This analysis shows a medium correlation between Professionalism and Clinical Skills and a weaker correlation between the Knowledge

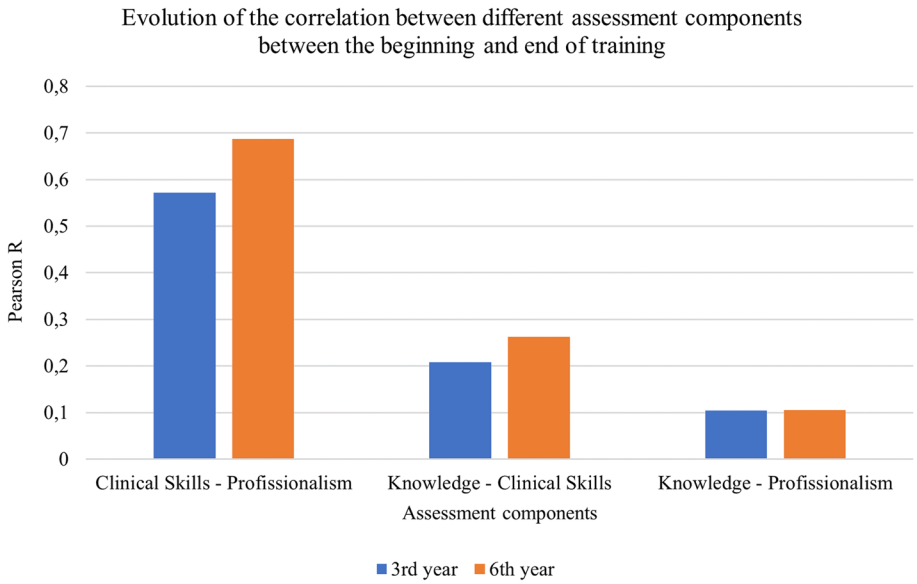

Fig. 2 Evolution of the correlation between different assessment components between the beginning and end of training

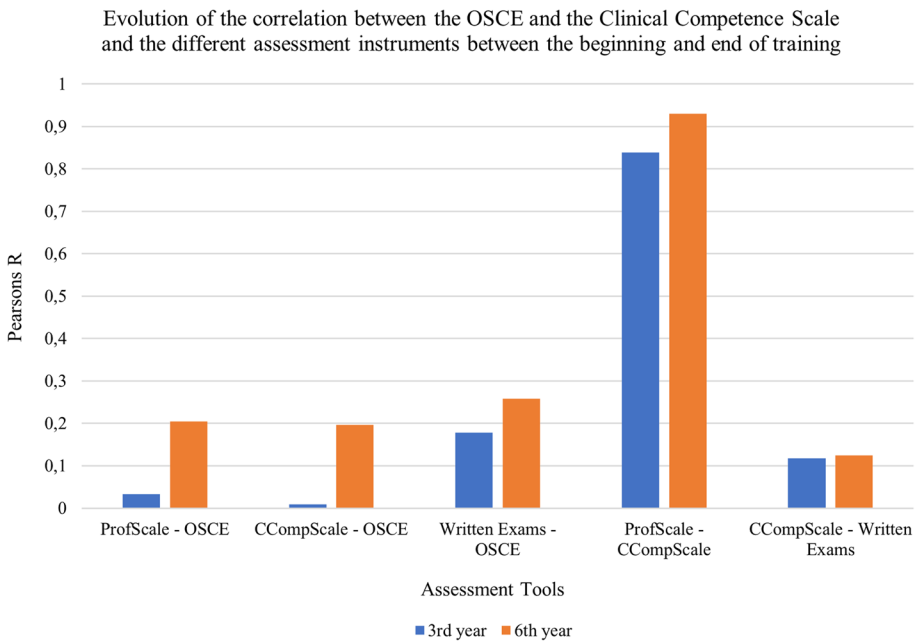

Fig. 3 Evolution of the correlation between the OSCE and the Clinical Competence Scale and the different assessment instruments between the beginning and end of training

component and both the Professionalism and Clinical Skills components. The fact that all components are correlated suggests an alignment between them and that one component can share similar characteristics with the other, which goes in line with the meaningful and the integrated learning theories proposals. For example, for a student to be successful in their clinical skills practice, they must possess a foundational knowledge basis to be able to adapt to the situation. On the other hand, it is also important to consider, especially where the correlation is stronger, the possibility of an excess of contamination between the different types of latent variables that those components are trying to measure.

The second aim of this study was to measure the longitudinal variation in correlations between different assessment components, which refers to the changes in the strength of the relationship between these components as they are measured at different points in time. It is important to consider longitudinal variation in correlations when interpreting the results of assessments, as variations in the strength of the relationship between different measures may indicate changes in the underlying construct being measured. This can be particularly important when assessing the effectiveness of an intervention or educational program, as variations in the correlations between different measures may indicate changes in the underlying skills or abilities being targeted by an intervention. These variations might also be of interest in predicting the performance of a group of students. For example, if the correlations between exams and clinical skills are strong early in medical school but weaken as students' progress through their education and begin to apply their knowledge in clinical settings, it may be less reliable to predict students' clinical skills based on their exam performance alone; instead, a range of assessment methods, including evaluations during clinical rotations and case-based learning, may be more predictive of future clinical skills. It is, thus, important for medical schools to consider the value of longitudinal variation in correlations between different components of assessment and to use a range of assessment methods to ensure that students are being adequately evaluated and prepared for future clinical practice. The variation of the correlation coefficients between the reported components can be explained by examining the specific trends and changes observed over the years in the longitudinal analysis.

Regarding Clinical Skills and Professionalism, the correlation coefficient remained consistently positive and statistically significant across all groups from 2011 to 2021, indicating a stable relationship where students who performed well in clinical skills also tended to demonstrate strong professionalism. Although there was some variation, the correlation remained medium to strong, suggesting that these two components are closely related and that their relationship is robust over time but also raising the question if there is an excess of information crossing between these components. This type of observation calls for a reappraisal of the process through which these assessments occur and eventually leads to a change in how instruments are being applied and increasing faculty development programs.

In the case of Knowledge and Clinical Skills, in the first two groups, there was no significant correlation; however, starting from the groups after 2013, a positive and statistically significant correlation began to emerge and showed a clear progression, reaching a maximum Pearson r value of 0.440 in the 2016–2019 group. This suggests that over time, as students progressed through their training, the relationship between their theoretical knowledge and clinical skills became stronger. This phenomenon can be explained by several factors: on one hand, the medical school was introducing the routine use of clinical vignettes in the written exams, with a simultaneous reduction of memory based items, that proved to be more discriminative; on the other hand, as the OSCEs were starting to be implemented in the medical school, there were some discrepancies between the assessors that may have introduced some bias in the scoring of these exams, that were mitigated through the development of a specific faculty development program.

At last, in the case of Knowledge and Professionalism, the correlation coefficient was generally weaker suggesting that while there is a positive relationship, it is less pronounced. The variability observed in the correlation coefficient throughout time could indicate that the relationship between knowledge and professionalism is more susceptible to fluctuations due to various factors, such as changes in curriculum, teaching methods, or assessment criteria during those periods. However, the authors believe that this positive correlation, even as a weaker correlation, is noticeable in two components that measure quite distinct, and apparently not related, constructs; one explanation it that this relationship is mediated by other factors (e.g., highly professional students may be more motivated to seek out opportunities to learn and improve their skills) [1, 13, 22]. Nevertheless, it is important to consider the context in which the correlation is observed and to carefully examine the nature of the relationship between professionalism and knowledge. It may be helpful to gather additional data from other institutions in future research to understand the relationship between these two constructs better and to identify any potential mediating or confounding factors that may be influencing the relationship. This can inform the development of strategies to support the professional development of individuals and to promote knowledge acquisition.

Importantly, the correlation between these measures can vary over time as students' abilities change. Thus, the third and final aim of the present study was to analyze the evolution between the beginning and the end of the training of the clinical cycle. Here, we noticed the relevance of the evolution in the correlations involving the clinical skills component, with a special interest between the professionalism component. In fact, this is a relevant result given that the group, the assessors, and the assessment methods remained relatively stable along time; for this reason, we decided to further analyze the different assessment methods used to assess clinical

skills. We found that there is stability between the written exams (that assess the knowledge component) and the other assessment methods used to assess clinical skills (OSCE and CCompScale), which confirms the existence of a common cognitive dimension in these instruments. Interestingly, all the other assessment methods (OSCE, CCompScale and ProfScale) showed a significant increase in the strength of the correlation between the 3rd and 6th year. We believe that this finding confirms the initial hypothesis that students during clinical training evolve in a multidimensional way that converge in a more coherent overall performance, with an approximation of performance amongst major competences such as Clinical Skills and Professionalism. To the best of our knowledge, the literature is scarce regarding the correlation between these two components, although some authors highlight the importance of one to the other, with significant positive correlations during medical school [10, 16].

Limitations

There are some limitations that should be considered when interpreting these results. First, this work took place in only one institution, lacking the variation in context. Second, the results regarding the Professionalism assessment and the Clinical Skills assessment with the use of the ProfScale and the CCompScale must be analysis with the knowledge that both these scales are assessed at the same time in a retrospective manner and by the same single assessor creating an excessive contamination between scales. In the future, similar analysis of other institutions will provide more insightful information and a better understanding of the patterns here described; also, different, and more independent assessment strategies for the Professionalism and Clinical Skills should be considered. Third, the authors recognize that other types of analysis could be made to assess the data here presented, such as a latent growth model analysis and the calculation of the deattenuated correlation coefficient; however, due to the heterogenicity and the complexity of the data, the authors considered that this type of analysis would raise other difficulties. And fourth, although our study's curricular units follow a sequential order and no significant simultaneous events were registered, we acknowledge that potential confounding variables, may not have been fully accounted for.

Strengths and future directions

This study's strengths lie in its comprehensive analysis of the longitudinal correlations between different assessment components in medical education, including a large sample size and an extended timeframe. By examining the relationships between Professionalism, Clinical Skills, and Knowledge, the study provides valuable insights into how these dimensions interact and evolve throughout medical training. The findings highlight the importance of using diverse assessment methods to capture the multifaceted development of medical students, ensuring that evaluations are both reliable and reflective of students' holistic growth. For future directions, research should explore these correlations in different educational contexts and investigate potential factors influencing these relationships. Also, future research could benefit from employing regression analysis or partial correlation coefficients to explore the contributions of potential confounding variables. Additionally, medical schools should consider refining assessment instruments and faculty development programs to enhance the alignment of their evaluation processes, ultimately contributing to better educational planning and improved outcomes for medical curricula.

Conclusions

With this work we propose that the development of different components of medical training is interconnected and integrated in a way that learning one component will affect the learning process of another. With focus on the assessment methodology, we also highlight the importance of understanding how different assessment components and instruments relate to be able to adjust assessment programs and measure the impact of educational interventions. Ultimately, this framework within an institution allows to better monitor and verify the quality of programmatic assessment processes.

Supplementary Information

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Supplementary Material 1.

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Authors' contributions
RS collected, analyzed, interpreted the data regarding the assessment of the medical students and contributed to the manuscript. CC contributed to the analysis, interpretation and writing of the manuscript. VHP contributed to the interpretation and was a major contributor in writing the manuscript. All authors read and approved the final manuscript

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Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee of the University of Minho (CEICVS-146/2021) (Appendix 1).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Alharbi NS, Alassaf AM, AlZamil AR, Alqarni BM, Alzahrani FA, Alsaif FB. Studying the association between knowledge of professionalism and demographic characteristics in king saud university medical students. Cureus. 2023;15(8):e44241.
2. Arnold L, Stern DT. What is Medical Professionalism? In: Stern DT, editor. Measuring Medical Professionalism. New York, NY: Oxford University Press; 2006. p. 15–37.
3. Ausubel DP. A subsumption theory of meaningful verbal learning and retention. J Gen Psychol. 1962;66:213–24.
4. Borowitz SM, Saulsbury FT, Wilson WG. Information collected during the residency match process does not predict clinical performance. Arch Pediatr Adolesc Med. 2000;154:256–60.
5. Boyse TD, Patterson SK, Cohan RH, Korobkin M, Fitzgerald JT, Oh MS, Gross BH, Quint DJ. Does medical school performance predict radiology resident performance? Acad Radiol. 2002;9(4):437–45.
6. Brothers TE, Wetherholt S. Importance of the faculty interview during the resident application process. J Surg Educ. 2007;64(6):378–85.
7. Cianciolo AT, Williams RG, Klamen DL, Roberts NK. Biomedical knowledge, clinical cognition and diagnostic justification: a structural equation model. Med Educ. 2013;47(3):309–16.
8. Durning SJ, Pangaro LN, Lawrence LL, Waechter D, McManigle J, Jackson JL. The feasibility, reliability, and validity of a program director's (supervisor's) evaluation form for medical school graduates. Acad Med. 2005;80:964–8.
9. Eze BUN, Edeh AJ, Ugochukwu AI. Comparing objective structured clinical examinations and traditional clinical examinations in the summative evaluation of final-year medical students. Niger J Surg. 2020;26(2):117–21.
10. Franco CAGDS, Franco RS, Lopes JMC, Severo M, Ferreira MA. Clinical communication skills and professionalism education are required from the beginning of medical training - a point of view of family physicians. BMC Med Educ. 2018;18(1):43.
11. Gonçalves M, Gonçalves N, Mendonça-Gonçalves M, Sousa AL, Morgado P, Sousa N, Costa P, Cerqueira J. Minho communication assessment scale development and validation. Acta Med Port. 2020;33(5):326–34.
12. Hafferty FW. Definitions of professionalism: a search for meaning and identity. Clin Orthop Relat Res. 2006;449:193–204.
13. Hultman CS, Halvorson EG, Kaye D, Helgans R, Meyers MO, Rowland PA, Meyer AA. Sometimes you can't make it on your own: the impact of a professionalism curriculum on the attitudes, knowledge, and behaviors of an academic plastic surgery practice. J Surg Res. 2013;180(1):8–14.
14. Lawal AO, Abiola AO, Habeebu MYM, Ojewola RW, Tijani KH. An assessment of the correlation between tests of clinical competence and tests of cognitive knowledge amongst Nigerian resident doctors in surgery. J West Afr Coll Surg. 2020;10(2):12–6.
15. Lee IA., Preacher KJ. 2013 Oct. Calculation for the test of the difference between two dependent correlations with no variable in common [Computer software]. Available from http://quantpsy.org.
16. Liu CI, Tang KP, Wang YC, Chiu CH. Impacts of early clinical exposure on undergraduate student professionalism-a qualitative study BMC Med Educ. 2022;22(1):435.
17. Lurie SJ, Mooney CJ. Relationship between clinical assessment and examination scores in determining clerkship grade. Med Educ. 2010;44(2):177–83.
18. Mansilla V. Integrative Learning: Setting the Stage for a Pedagogy of the Contemporary. Peer Review. 2008. Vol. 10, Issue 4.
19. Miller A, Archer J. Impact of workplace based assessment on doctors' education and performance: a systematic review. BMJ. 2010;24(341):c5064.
20. Miller GE. The assessment of clinical skills/competence/performance. Acad Med. 1990;65(9 Suppl):S63–7.
21. Newble DI, Swanson DB. Psychometric characteristics of the objective structured clinical examination. Med Educ. 1988;22(4):325–34.
22. Noll DR. Evidence-based medicine and osteopathic medicine: no paradox. J Am Osteopath Assoc. 2015;115(3):124–5.
23. Norcini J, Burch V. Workplace-based assessment as an educational tool: AMEE Guide No. 31 Med Teach. Med Teach. 2007;29(9):855–71.
24. Ramlogan S, Raman V. An educational approach for early student self-assessment in clinical periodontology. BMC Med Educ. 2022;22(1):33.
25. Schuwirth LW, van der Vleuten CP. ABC of learning and teaching in medicine: Written assessment. BMJ. 2003;326(7390):643–5.
26. Sheets KJ, Anderson WA, Alguire PC. Curriculum development and evaluation in medical education. J Gen Intern Med. 1992;7:538–43.
27. Steiger JH. Tests for comparing elements of a correlation matrix. Psychol Bull. 1980;87:245–51.
28. Swanson DB, van der Vleuten CP. Assessment of clinical skills with standardized patients: state of the art revisited. Teach Learn Med. 2013;25(Suppl 1):S17-25.
29. Tang B, Hanna GB, Carter F, Adamson GD, Martindale JP, Cuschieri A. Competence assessment of laparoscopic operative and cognitive skills: Objective Structured Clinical Examination (OSCE) or Observational Clinical Human Reliability Assessment (OCHRA). World J Surg. 2006;30(4):527–34.
30. Van der Vleuten CP, Van Luyk SJ, Beckers HJ. A written test as an alternative to performance testing. Med Educ. 1989;23(1):97–107.
31. Van der Vleuten CP, Swanson DB. Assessment of clinical skills with standardized patients: State of the art. Teach Learn Med. 1990;2(2);58–76.
32. Greenburg DL, Durning SJ, Cohen DL, Cruess D, Jackson JL. Identifying medical students likely to exhibit poor professionalism and knowledge during internship. J Gen Intern Med. 2007;22(12):1711–7.

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