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Peer learning in higher education: An example of practices

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Summary. — Nowadays, academic institutions face the challenges of an increasing number of student enrolments as well as dropouts. An important factor which allows predicting learner dropout is the number of university educational credits gained across the first term in the first academic year. Since active methods enhance students' learning more than traditional lectures, a possible effect of their implementation in an academic course might be an increase in the pass rate in final examinations, thus contributing to moderate the learners' dropouts. In this perspective, a case study was implemented to examine whether integrating peer learning into traditional physics lectures through the use of technology may have positive effects on student learning in large size classes. This study aimed at 1) outlining how this educational method was implemented in the context of an academic physics course at Politecnico di Milano, and 2) illustrating some preliminary results regarding the final achievement of the students involved in this teaching methodology.

1. – Introduction

A critical issue for STEM faculties is that few students achieve a degree, being the dropout rate considerable in the first years of higher education [1-4]. Even worse, roughly twice as many women abandon STEM fields as do men [5]. By way of illustration, although approximately one-third of university students worldwide leave their academic institution in their first year [6], it has been estimated that roughly four out of ten undergraduates who entered a US college to study a STEM subject eventually chose a non-STEM programme [7]. In this context, Italy is no exception with 28.3% of its university population dropping out and about 20% abandoning their tertiary institution within the first two academic years [8].

While in the 1960s student retention or the lack thereof was ascribed to the single learner and was considered the result of individual attributes, skills and motivation, this view began to change in the 1970s [9], when the relationship between individuals and

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society was reconsidered and the emphasis significantly shifted to the role of the environment, in particular the academic institution [10-12]. Tinto [12, 13] proposed a detailed, longitudinal model based on the concept of integration and the patterns of interaction between the learners and other members of the university, with specific reference to the critical first year of attendance.

As regards learner retention, further studies [14, 15] have highlighted that students' involvement in the classroom plays a paramount role given that the classroom is the place where they meet each other and engage with the academic institution. Actually, involvement, or what is increasingly being referred to as engagement, can make a difference during the delicate first year of higher education [16]. According to Tinto [14, 15], implementing educational innovation and renewing the teaching practice contribute in a decisive way to learners' engagement which, in turn, results in a strengthened student persistence. Furthermore, Eris *et al.*'s longitudinal study [17] shows that notable differences between persistent and non-persistent engineering students may be the results of their family attitude to science and technology. Moreover, high school mentors may influence both learners' motivation to start an engineering career, and confidence in their maths and science skills.

However, it has been emphasised that some individual factors like a lack of interest, disappointment in the subject, below average performance, and loss of self-efficacy [18, 19] may lead to attrition in STEM faculties. Furthermore, institutional factors such as poor teaching or mentoring and excessive rigour of the programme should not be underestimated [20, 21].

Given that limiting the dropout rate represents a challenging task in STEM faculties, the ever-increasing use of data mining techniques in the last decade has allowed to better estimate the students' features which can lead them to abandon their academic institution [22-25]. In a recent study based on administrative data from the Italian Politecnico di Milano, it has been pointed out that the most important factor which allows predicting Politecnico di Milano students dropout is the number of university educational credits (CFU) gained across the first term of the first academic year [26]. As a consequence, to enhance the pass rate of academic courses, especially if they are perceived as a challenge by learners, could allow to mitigate the dropout phenomenon.

As far as Physics is concerned, the literature on Physics pedagogy has demonstrated that learning this discipline often proves to be a notable and demanding testing ground for many university students who are taking courses in STEM faculties [27-29]. By way of illustration, Bozzi *et al.* [30] examined the exam marks earned by the engineering undergraduates ($N = 2.350$) matriculated at the Politecnico di Milano, Italy. These undergraduates attended a physics course in the first term of academic year 2018–2019. Findings indicate that fewer than six students out of ten completed their final exam before the second academic semester began, although on average their mark was lower than 24/30. It is worth noticing that the highest mark is 30/30 cum laude in the Italian university context, while 24/30 is not deemed as a high mark.

Stains *et al.* [31] argue that traditional lectures are still largely used in most of the physics courses offered in higher education across the world. Several studies have compared traditional physics lectures and the effectiveness of interactive-engagement methodologies. Some meta-analyses [32, 33] indicate that active learning is more beneficial, particularly in terms of conceptual understanding [34, 35]. Peer Instruction [36-41], Problem-Based Learning [42] and Student-Centred Activities for Large Enrolment Undergraduate Programs [43-45], are among the most noticeable pedagogical strategies designed and implemented in numerous North American universities which offer physics courses. These student-centred approaches aim to maximise student learning potential through learners' intellectual and emotional engagement. The core element that allows categorising an educational methodology as active learning is definitely the students' involvement in the learning process [46].

In line with the cognitivist and socio-cultural theory of learning, empirical research in higher education has recognised two types of learning, namely deep learning and surface learning [47]. Whereas the former consists of a critical analysis of new facts and ideas, linking them with already existing cognitive structures and shaping innumerable connections among these ideas, the latter assimilates them uncritically, featuring a tendency to store them as isolated and detached items [48, 49]. On the whole, the theory and research into learning and, specifically, learning in higher education have made the important point that active methods are effective in generating and activating meaningful, situated, and deep learning [49, 50].

However, some factors seem to complicate lecturers' adoption of active methods, which hinders their spread in academia. Indeed, although they are globally spread, even if unevenly, in academic institutions worldwide, active learning strategies are still disregarded on a large scale in STEM curricula more frequently than one would anticipate. While their implementation in physics courses has truly spread in a growing, though still restricted, number of academic institutions in the US [31], this is not the case for European universities, and Italian universities are no exception [50-52]. Indeed, among the most frequent reasons for resistance to the implementation of active learning practices, practitioners' limited resources, a dearth of time, and a limited departmental as well as institutional support feature as major hindrances, with problems concerning syllabus content coverage as another important deterrent [53, 54].

A further issue which merits attention is the adoption of active teaching methods, which might prove to be one of the most challenging tasks due to the complex logistics which large size lectures often demand. Several researchers argue that increasingly crowded classes are one of the unfortunate by-products of the massification of higher education [55-57]. To compensate for this unwelcome phenomenon, instructors often opt for traditional lectures although they frequently generate lower acquisition of knowledge and skills, given the fact that in traditional lectures students chances of interacting with their instructors and having a feedback from them tend to be limited [58]. Numerous research studies have shown that overcrowded classrooms may hinder students' acquisition of knowledge and skills. In this regard, large size classes represent an alleged factor in making lecturers deem traditional lectures as the only feasible teaching methodology [31, 59, 60]. Importantly, studies on active learning which have been undertaken in Europe frequently engage small or medium size classes [35, 61, 62]. As a consequence, university lecturers who need to address the problems of large size formats can only rely on little evidence of how to incorporate active pedagogies in their teaching context [63].

Within the realm of active strategies, peer learning (PL) is likely to be considered inappropriate in overcrowded settings, in spite of its major contribution to effective learning in higher education [64]. Contrary to what one might think, PL does not refer to a unique, homogeneous educational methodology and, over time, ten different types of PL have been identified, *inter alia* peer feedback sessions in class, student-to-student learning partnerships, study groups, student-led workshops, and team projects [65,66]. According to Boud *et al.* [66], PL consists in the adoption of learning and teaching strategies in which students learn from and with each other without the immediate support of a teacher. Its goal is promoting attitudinal change or conceptual understanding [66]. Beyond the alternative models, however, a PL distinctive feature is the interdependent learning based on participants sharing their ideas, knowledge and experience in a mutually beneficial endeavour [67]. Another noteworthy hallmark of PL is that all the participants have the same role: nobody interprets the role of the expert practitioner or teacher, even though some peers might have previous valuable experience or expertise [68]. In our study, a PL session includes four different steps: a) the learners individually answer some multiple-choice items, which allows for a brief reflection on the topic. According to Nicol and Boyle [69] and Nielsen *et al.* [70], this introductive thinking time appears to be particularly beneficial for the subsequent group discussion; b) the discussion among peers in small groups; c) the students individually answer the same items tackled in the previous phase a); and d) a brief explanation of the items from the instructor. Not only do these PL sessions allow learners to experience effective cooperative feedback discussions [71], which are proven to be very powerful in promoting learning [72], but they also represent a feedback from the students to the instructor, which is even more powerful [71].

In conclusion, a complete transition of physics courses in higher education from a teacher-centred pedagogy to a completely student-centred approach, especially within the context of large size classes, appears to be anything but feasible or satisfactory in the next few years. Thus, it seems to be sensible and perhaps unavoidable to examine the educational potential of a combined and synergistic use of traditional lectures and an active learning method like PL, supported by the methodical use of technology. Furthermore, it would be appropriate at this point to attempt to examine some effective ways of using this synergistic approach in large size classes. In the Italian scenario, despite the hegemonic role which is still played by transmittal lectures in academic programmes, Politecnico di Milano has started to include active learning in large size formats with promising results, an endeavour which deserves further investigation [73-77].

2. – Method

2˙1. *Research design.* – Since active methods employed in university classes enhance students' learning more than traditional lectures even in the context of large size formats [33, 75], a possible effect of their implementation in an academic course might be an increase in students' pass rate in final examinations. In this perspective, in academic year 2021–2022, a physics course usually offered to Politecnico di Milano freshmen has been selected to implement a case study aimed at examining the possible positive effects on students learning of an integrated use of PL, technology, and traditional physics lectures in large size classes. Differently from other active methods, like peer discussion [37], employed in several universities, this innovative teaching methodology is characterised by the integration of active methods and traditional lectures rather than completely replacing the latter with the former. Moreover, a further innovation is the adoption of active methods in the context of large size formats.

This study aimed at 1) outlining how this educational method was implemented in the context of an academic physics course, and 2) illustrating some preliminary results regarding the final achievement of the students involved in this teaching methodology.

2˙2. *Research context and participants.* – The case study was conducted at Politecnico di Milano, located in the North-Western part of Italy, in the first term of academic year 2021–2022, and involved an academic basic physics course called "Fisica Sperimentale A+B" ("Experimental Physics A+B"). It focused on some mechanics and electromagnetism topics and granted 10 CFU to the learners who passed its final exam. While mechanics contents regarded Newtonian mechanics of material points, energy and energy transfer, momentum and collisions, oscillatory motion and gravity, electromagnetism topics concerned electric forces, electric fields, electric potential, conductors, insulators, electric current, magnetic forces and magnetic fields.

This physics course is usually attended by both 19-year-old learners enrolled on the first year of Chemical Engineering and freshmen who study Materials and Nanotechnology Engineering. The participants, all of whom accepted to declare their gender, were 202, with 62 females and 140 males. Owing to the problems posed by the COVID-19 pandemic which still conditioned ordinary life of the Italian citizens at that time, students could opt to attend the course in presence, online or in a blended mode. Politecnico di Milano administered an online questionnaire to all the students enrolled in the academic course "Fisica Sperimentale A+B" at the end of the first term of academic year 2021–2022. In quantitative terms, 167 students out of 202 (82.7%) answered it, 87 learners (52.1%) stated that their in-presence participation to lectures and drills was higher than 50%, while 61 (36.5%) claimed online attendance higher than 50%. Finally, the participation to the course of 19 learners (11.4%) was lower than 50%. Notwithstanding that, the university regulation did not require mandatory attendance of this course and learners were not compelled to attend it, the average number of participants in each lecture was about 100 or higher; therefore, the size of the class might be regarded as large.

In academic year 2021–2022 "Fisica Sperimentale A+B" lasted for 100 hours, 57 hours of which were dedicated to traditional lectures within a theoretical framework, 40 hours consisted in drills aimed to develop and heighten the students' problem-solving skills, and 3 hours were devoted to PL activities. The overall number of PL sessions periodically offered to the learners during the course in 2021–2022, which began in the middle of September 2021 and finished in last decade of December 2021, was seven. Figure 1 illustrates the physics course design.

At the beginning of every physics course scheduled in the first term of that academic year, like Fisica Sperimentale A+B, an initial questionnaire was administered to all Politecnico di Milano freshmen enrolled on those courses. This questionnaire consisted of 18 multiple choice items, 6 of which focused on Mechanics issues, 6 were based on Thermodynamics topics and the last 6 dealt with Electromagnetism subjects. The students gained 1 point for each correct answer and 0 points in all other cases. Moreover, the students could use their own electronic devices to answer the questionnaire. Through this tool we could compare the initial level of knowledge in physics between the learners attending Fisica Sperimentale A+B and the other Politecnico di Milano freshmen.

As aforementioned, students experienced seven PL sessions periodically during the

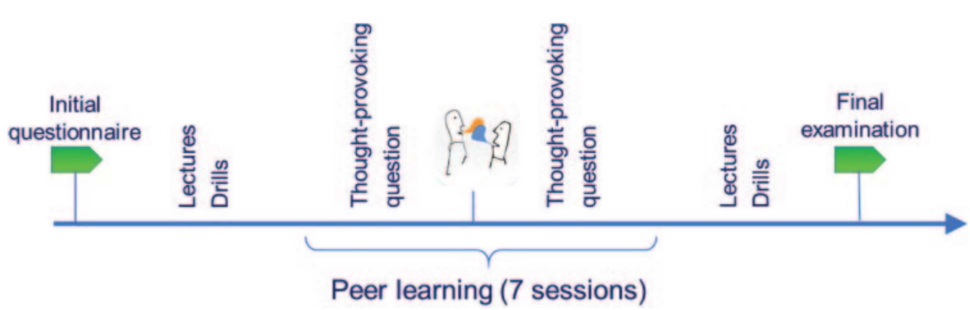


Fig. 1. – "Fisica Sperimentale A+B" design in academic year 2021–2022.

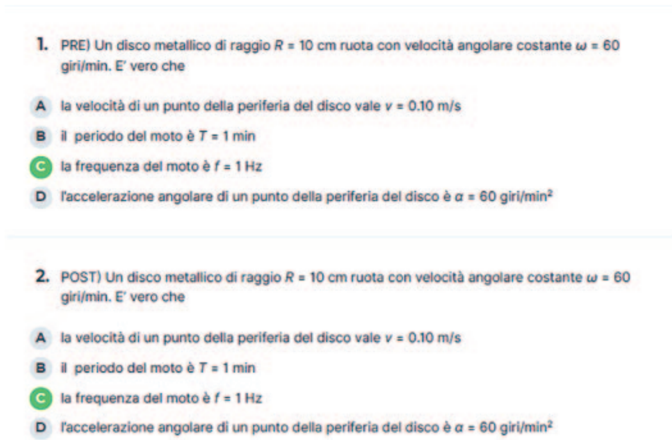
course, four of which dealing with some mechanics topics and three focused on electromagnetism contents. Every PL session started with a questionnaire administered to the students through the online portal Socrative, whose use as a student response system has been broadly investigated in relation with interactive teaching [78,79]. The questionnaire consisted of three multiple choice items and the participants had to answer each question using their own electronic devices, coherently to the satisfactory outcomes that have been documented with reference to the Bring Your Own Device approach [80]. Indeed, it has been emphasised that the use of technology in higher education teaching and learning contexts reinforces learners' engagement [81] and academic performance [82,83]. Furthermore, PL decidedly benefits from its use [82]. The time allotted to each item, for which four possible alternatives were provided with only one correct answer, was 1.50 min. Furthermore, all these thought-provoking questions were different from the ones administered during the initial questionnaire. Immediately after answering the first question and without getting any feedback on accuracy, participants were asked to discuss the item in small groups (3–4 people) for few minutes (3–5 min) with their fellow learners sitting next to them. In Mazur Peer Instruction method, the lecturer recommended each participant to try to persuade the other students in the small group that their answer to the question was correct by explaining their underlying reasoning. Moreover, the lecturer moved around the classroom listening to them and asking questions to help learners in their reasonings [84]. On the contrary, during our peer discussion phase, the instructor was not involved in the discussion among the students and did not move around the room or listen to their debate. As aforementioned, PL sessions also represented important occasions of feedback from learners to the instructor, who easily set the pace of their work and ensured unobtrusively the proper conduct of this educational activity. Indeed, the aim of the discussion phase was not only to seek out the correct answer or to convince the other learners and reach a shared answer, but to discover the complexity of the item topic by tackling it from different perspectives without any influence of the teacher.

At the end of this debate, they retook separately the same question and had again 1.50 min to reflect and draw their own conclusions on the issue previously discussed with their peers. Then they focused on the following item. Finally, the correct answer to each item was given with a brief explanation of the reason why the other alternatives were wrong (3–5 min). Table I summarises the stages of a PL session.

Figure 2 shows an example of a thought-provoking question.

TABLE I. – *Stages of a PL session.*

Stage	Number of times	Allotted time (min)
Thought-provoking question before discussion among peers	3	4.5
Discussion among peers	3	9–15
Thought-provoking question after discussion among peers	3	4.5
Instructor explanation	1	3–5



1. PRE) Un disco metallico di raggio R = 10 cm ruota con velocità angolare costante ω = 60 giri/min. E' vero che

A la velocità di un punto della periferia del disco vale v = 0.10 m/s

B il periodo del moto è T = 1 min

C la frequenza del moto è f = 1 Hz

D l'accelerazione angolare di un punto della periferia del disco è α = 60 giri/min^2

2. POST) Un disco metallico di raggio R = 10 cm ruota con velocità angolare costante ω = 60 giri/min. E' vero che

A la velocità di un punto della periferia del disco vale v = 0.10 m/s

B il periodo del moto è T = 1 min

C la frequenza del moto è f = 1 Hz

D l'accelerazione angolare di un punto della periferia del disco è α = 60 giri/min^2

Fig. 2. – An example of a thought-provoking question administered both before (PRE) and after (POST) the discussion among peers.

Table II. – *Academic physics course Fisica Sperimentale A+B: total number of students attending, number of students who passed and failed the final exam with reference to 2021–2022.*

Academic year	PL	Total number of students	Pass number (percentage)	Failure number (percentage)
2021–2022	Yes	202	88 (43.56)	114 (56.44)

3. – Results

The data collected were examined through the statistical opensource software R (version 4.2.2) in the integrated development environment RStudio (`https://rstudio.com/` accessed on 23 June 2023). The statistical significance was beforehand established at level $\alpha = 0.05$.

To have a preliminary evaluation of the effectiveness of our innovative integrated educational strategy in large size academic classes, we calculated the pass rate of freshmen attending Fisica sperimentale A+B in their Physics course final exam during the first examination session, which lasted from January 2022 to February 2022. Table II summarises these results.

4. – Discussion and outcomes for the future

In the context of a physics course offered to some Politecnico di Milano Engineering freshmen across the first term of academic year 2021–2022, a case study was implemented to investigate the effectiveness of a new pedagogical practice, based on the integration of PL activities, strengthened by the use of technology, traditional lectures, and drills. We preliminarily demonstrated that the knowledge in Physics of the students enrolled on Fisica Sperimentale A+B in academic year 2021–2022 did not differ from the one of the other freshmen who attended a basic physics course in the same academic term.

Although the former achieved a mean score in the initial questionnaire which was slightly lower than the latter, their mean score (5.54 and 6.02, respectively) appeared to be much lower than the maximum score potentially achievable, *i.e.*, 18. It implies that all these learners appeared to be slightly weak in Physics and the COVID-19 pandemic probably played a paramount role to explain these results.

A preliminary analysis of the final exam results highlighted that the pass rate was about 44% and this may suggest a positive influence of the PL sessions. However, we would like to emphasise that no conclusion can be drawn on the basis of these descriptive statistics analyses and these promising results need to be further investigated. A possible future step could consist in comparing the performance of our studied group with an appropriate independent control group through inferential analysis.

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REFERENCES

[1] Coates H. and Ranson L., *Dropout DNA, and the Genetics of Effective Support* (ACER) 2011.
[2] Chen X., *STEM Attrition: College Students' Paths Into and Out of STEM Fields (NCES 2014-001)* (National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education, Washington, DC) 2013.
[3] Dai T. and Cromley J. G., *Contemp. Educ. Psychol.*, **39** (2014) 233.
[4] French B. F., Immekus J. C. and Oakes W. C., *J. Eng. Educ.*, **94** (2005) 419.
[5] Preston A. E., *Issues Sci. Technol.*, **20** (2004) 69.
[6] OECD, *Education Today 2013: The OECD Perspective* (OECD Publishing, Paris) 2012.
[7] National Science Board, *Science and Engineering Indicators 2012* (US National Science Foundation (NSF), Arlington VA, USA) 2012.
[8] ANVUR, *Anvur: Rapporto biennale sullo stato del sistema universitario e della ricerca* (ANVUR) 2018.
[9] Tinto V., *J. Coll. Stud. Retent.: Res., Theory Pract.*, **8** (2006) 1.
[10] Spady W. G., *Interchange*, **1** (1970) 64.
[11] W. G. Spady, *Interchange*, **2** (1971) 38.
[12] Tinto V., *Rev. Educ. Res.*, **45** (1975) 89.
[13] Tinto V., *Leaving College: Rethinking the Causes and Cures of Student Attrition*, 1st edition (University of Chicago Press) 1987.
[14] Tinto V., *J. Higher Educ.*, **68** (1997) 599.
[15] Tinto V., Russo P. and Kadel S., *Community Coll. J.*, **64** (1994) 26.
[16] Upcraft M. L., Gardner J. N. and Barefoot B. O., *Challenging and Supporting the First-Year Student: A Handbook for Improving the First Year of College* (Jossey-Bass, An Imprint of Wiley) 2004.
[17] Eris O., Chachra D., Chen H. L., Sheppard S., Ludlow L., Rosca C., Bailey T. and Toye G., *J. Eng. Educ.*, **99** (2010) 371.
[18] Seymour E. and Hewitt N. M., *Talking about Leaving: Why Undergraduates Leave the Sciences* (Westview Press, Boulder (Colo.)) 1997.
[19] Seymour E. and Hunter A.-B. (Editors), *Talking about Leaving Revisited: Persistence, Relocation, and Loss in Undergraduate STEM Education* (Springer International Publishing) 2019.
[20] Meyer M. and Marx S., *J. Eng. Educ.*, **103** (2014) 525.

[21] President's Council of Advisors on Science and Technology, *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics. Report to the President* (Executive Office of the President, Washington, DC) 2012.

[22] Burgos C., Campanario M. L., de la Peña D., Lara J. A., Lizcano D. and Martínez M. A., *Comput. Electr. Eng.*, **66** (2018) 541.

[23] Fontana L., Masci C., Ieva F. and Paganoni A. M., *Data*, **6** (2021) 74.

[24] Kemper L., Vorhoff G. and Wigger B. U., *Eur. J. Higher Educ.*, **10** (2020) 28.

[25] de Freitas S., Gibson D., Du Plessis C., Halloran P., Williams E., Ambrose M., Dunwell I. and Arnab S., *Br. J. Educ. Technol.*, **46** (2015) 1175.

[26] Cannistrà M., Masci C., Ieva F., Agasisti T. and Paganoni A. M., *Stud. Higher Educ.*, **47** (2022) 1935.

[27] Angell C., Guttersrud O., Henriksen E. K. and Isnes A., *Sci. Educ.*, **88** (2004) 683.

[28] Örnek F., Robinson W. R. and Haugan M. R., *Sci. Educ. Int.*, **18** (2007) 165.

[29] Redish E. F., Scherr R. E. and Tuminaro J., *Phys. Teach.*, **44** (2006) 293.

[30] Bozzi M., Balossi B., Sieno L. D., Ganzer L., Gondoni P., Genco I., Minnai C., Pini A., Rezoagli F., Zanoletti M. and Zani M., in *ICERI2019 Proceedings* (IATED, Valencia, ES) 2019, pp. 2237–2243.

[31] Stains M., Harshman J., Barker M. K., Chasteen S. V., Cole R., DeChenne-Peters S. E., Eagan M. K. jr., Esson J. M., Knight J. K., Laski F. A., Levis-Fitzgerald M., Lee C. J., Lo S. M., McDonnell L. M., McKay T. A., Michelotti N., Musgrove A., Palmer M. S., Plank K. M., Rodela T. M., Sanders E. R., Schimpf N. G., Schulte P. M., Smith M. K., Stetzer M., Van Valkenburgh B., Vinson E., Weir L. K., Wendel P. J., Wheeler L. B. and Young A. M., *Science*, **359** (2018) 1468.

[32] Hake R. R., *Am. J. Phys.*, **66** (1998) 64.

[33] Freeman S., Eddy S. L., McDonough M., Smith M. K., Okoroafor N., Jordt H. and Wenderoth M. P., *Proc. Natl. Acad. Sci. U.S.A.*, **111** (2014) 8410.

[34] McDaniel M. A., Stoen S. M., Frey R. F., Markow Z. E., Hynes K. M., Zhao J. and Cahill M. J., *Phys. Rev. Phys. Educ. Res.*, **12** (2016) 0201441.

[35] Schiltz G., Feldman G. and Vaterlaus A., *J. Phys.: Conf. Ser.*, **1286** (2019) 012019.

[36] Korpas G. S., Kahrs M. S. and Andersen T. H., in *Varietas Delectat... Complexity Is the New Normality* (European Society for Engineering Education, SEFI) 2019, pp. 651–657.

[37] Crouch C. H. and Mazur E., *Am. J. Phys.*, **69** (2001) 970.

[38] Wood A. K., Galloway R. K., Donnelly R. and Hardy J., *Phys. Rev. Phys. Educ. Res.*, **12** (2016) 010140.

[39] Rudolph A. L., Lamine B., Joyce M., Vignolles H. and Consiglio D., *Phys. Rev. ST Phys. Educ. Res.*, **10** (2014) 010103.

[40] Zhang P., Ding L. and Mazur E., *Phys. Rev. Phys. Educ. Res.*, **13** (2017) 010104.

[41] Dancy M., Henderson C. and Turpen C., *Phys. Rev. Phys. Educ. Res.*, **12** (2016) 010110.

[42] Duch B. J., *J. Coll. Sci. Teach.*, **15** (1996) 326.

[43] Beichner R. J., in *Research-Based Reform of University Physics*, edited by Redish E. F. and Cooney P. J., (College Park, MD) 2007, pp. 1–42.

[44] Foote K., Knaub A., Henderson C., Dancy M. and Beichner R. J., *Phys. Rev. Phys. Educ. Res.*, **12** (2016) 010103.

[45] Foote K. T., Neumeyer X., Henderson C., Dancy M. H. and Beichner M. H., *Int. J. STEM Educ.*, **1** (2014) 10.

[46] Fraser J. M., Timan A. L., Miller K., Dowd J. E., Tucker L. and Mazur E., *Rep. Prog. Phys.*, **77** (2014) 032401.

[47] Marton F. and Säljö R., *Br. J. Educ. Psychol.*, **46** (1976) 4.

[48] Biggs J. B., *Teaching for Quality Learning at University: What the Student Does* (Society for Research into Higher Education; Open University Press, Philadelphia; Buckingham) 1999.

[49] Ramsden P., *Learning to Teach in Higher Education* (Routledge) 2002.
[50] Ghislandi P. and Raffaghelli J., *Form. Insegn.*, **12** (2014) 57.
[51] Buhovac M., *The European Higher Education Area in 2015: Bologna Process Implementation Report* (European Union, Luxembourg: Publications Office of the European Union) 2018.
[52] Ranieri M., Raffaghelli J. E. and Bruni I., in *Faculty Development for Digital Teaching and Learning* (IGI Global) 2019, pp. 77–98.
[53] Deslauriers L., McCarty L. S., Miller K., Callaghan K. and Kestin G., *Proc. Natl. Acad. Sci. U.S.A.*, **116** (2019) 19251.
[54] Silverthorn D. U., Thorn P. M. and Svinicki M. D., *Am. J. Physiol. - Adv. Physiol. Educ.*, **30** (2006) 204.
[55] Hornsby D. J. and Osman R., *Higher Educ.*, **67** (2014) 711.
[56] Palfreyman D., Tapper T. and Thomas S., *Accountability in Higher Education: Global Perspectives on Trust and Power*, 1st edition (Routledge) 2011.
[57] Scott P., *The Meanings of Mass Higher Education* (Open University Press, Buckingham, UK) 1995.
[58] Trees A. R. and Jackson M. H., *Learn., Media Technol.*, **32** (2007) 21.
[59] Deslauriers L., Schelew E. and Wieman C., *Science*, **332** (2011) 862.
[60] Henderson C. and Dancy M. H., *Phys. Rev. ST - Phys. Educ. Res.*, **3** (2007) 020102.
[61] Leinonen R., Asikainen M. A. and Hirvonen P. E., *Phys. Rev. Phys. Educ. Res.*, **13** (2017) 010114.
[62] Wood A. K., Galloway R. K., Hardy J. and Sinclair C. M., *Phys. Rev. ST - Phys. Educ. Res.*, **10** (2014) 020001.
[63] Andersen T. H., Marøy Ø., Järvinen H.-M. and Korpas G. S., in *Engaging Engineering Education* (European Society for Engineering Education SEFI) 2020, pp. 594–600.
[64] Pellegrini M., *Form@re-Open J. Form. Rete*, **20** (2020) 128.
[65] Griffiths S., Houston K. and Lazenbatt A., *Enhancing Student Learning through Peer Tutoring in Higher Education* (University of Ulster, Coleraine) 1995.
[66] Boud D., Cohen R. and Sampson J., *Assess. Eval. Higher Educ.*, **24** (1999) 413.
[67] Boud D.,, in *Developing Student Autonomy in Learning*, 2nd edition (Routledge, London (UK)) 1988.
[68] Boud D.,, in *Peer Learning in Higher Education: Learning from and with Each Other* (Routledge, London (UK)) 2014.
[69] Nicol D. J. and Boyle J. T., *Stud. Higher Educ.*, **28** (2003) 457.
[70] Nielsen K. L., Hansen G. and Stav J. B., *Stud. Higher Educ.*, **41** (2016) 124.
[71] Hattie J. and Clarke S., *Visible Learning: Feedback* (Routledge, London) 2018.
[72] Hattie J., *Visible Learning: The Sequel: A Synthesis of Over 2,100 Meta-Analyses Relating to Achievement* (Routledge, London and New York) 2023.
[73] Bozzi M., Raffaghelli J. and Zani M., in *ICERI2018 Proceedings* (IATED, Seville, Spain), 2018, pp. 8739–8747.
[74] Raffaghelli J., Ghislandi P., Sancassani S., Canal L., Micciolo R., Balossi B., Bozzi M., Di Sieno L., Genco I., Gondoni P., Pini A. and Zani M., *Educ. Media Int.*, **55** (2018) 301.
[75] Bozzi M., Raffaghelli J. E. and Zani M., *Educ. Sci.*, **11** (2021) 67.
[76] Commission's Expert Group on Quality Investment in Education and Training, Y. Directorate-General for Education, Fack G., Agasisti T., Bonal X., De Witte K., Dohmen D., Haase S., Hylen J., McCoy S., Neycheva M., Pantea M. C., Pastore F., Pausits A., Poder K., Puukka J. and Velissaratou J., *Interim Report of the Commission Expert Group on Quality Investment in Education and Training* (Publications Office of the European Union, LU) 2022.
[77] Y. Directorate-General for Education, *Investing in Our Future: Quality Investment in Education and Training* (Publications Office of the European Union, LU) 2022.
[78] Guarascio A. J., Nemecek B. D. and Zimmerman D. E., *Curr. Pharm. Teach. Learn.*, **9** (2017) 808.

[79] Lim W. N., in *2017 IEEE Global Engineering Education Conference (EDUCON)* (IEEE) 2017, pp. 404–412.
[80] Afreen R., *Int. J. Emerg. Trends Technol. Comput. Sci.*, **3** (2014) 4.
[81] Blasco-Arcas L., Buil I., Hernández-Ortega B. and Sese F. J., *Comput. Educ.*, **62** (2013) 102.
[82] Caldwell J. E., *CBE-Life Sci. Educ.*, **6** (2007) 9.
[83] Mayer R. E., Stull A., DeLeeuw K., Almeroth K., Bimber B., Chun D., Bulger M., Campbell J., Knight A. and Zhang H., *Contemp. Educ. Psychol.*, **34** (2009) 51.
[84] Crouch C. H., Watkins J., Fagen A. P. and Mazur E., in *Research-Based Reform of University Physics*, edited by Redish E. F. and Cooney P., (American Association of Physics Teachers) 2007.
[85] Sawilowsky S., *J. Mod. Appl. Stat. Methods*, **8** (2009) 597.