



AALBORG UNIVERSITY
DENMARK

Aalborg Universitet

Problem-based projects in medical education

extending PBL practices and broadening learning perspectives

Stentoft, Diana

Published in:

Advances in health sciences education : theory and practice

DOI (link to publication from Publisher):

[10.1007/s10459-019-09917-1](https://doi.org/10.1007/s10459-019-09917-1)

Creative Commons License

CC BY-NC-ND 4.0

Publication date:

2019

Document Version

Accepted author manuscript, peer reviewed version

[Link to publication from Aalborg University](#)

Citation for published version (APA):

Stentoft, D. (2019). Problem-based projects in medical education: extending PBL practices and broadening learning perspectives. *Advances in health sciences education : theory and practice*, 24(5), 959-969. <https://doi.org/10.1007/s10459-019-09917-1>

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- ? Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- ? You may not further distribute the material or use it for any profit-making activity or commercial gain
- ? You may freely distribute the URL identifying the publication in the public portal ?

Take down policy

If you believe that this document breaches copyright please contact us at vbn@aub.aau.dk providing details, and we will remove access to the work immediately and investigate your claim.

Dear Author,

Here are the proofs of your article.

- You can submit your corrections **online**, via **e-mail** or by **fax**.
- For **online** submission please insert your corrections in the online correction form. Always indicate the line number to which the correction refers.
- You can also insert your corrections in the proof PDF and **email** the annotated PDF.
- For fax submission, please ensure that your corrections are clearly legible. Use a fine black pen and write the correction in the margin, not too close to the edge of the page.
- Remember to note the **journal title**, **article number**, and **your name** when sending your response via e-mail or fax.
- **Check** the metadata sheet to make sure that the header information, especially author names and the corresponding affiliations are correctly shown.
- **Check** the questions that may have arisen during copy editing and insert your answers/ corrections.
- **Check** that the text is complete and that all figures, tables and their legends are included. Also check the accuracy of special characters, equations, and electronic supplementary material if applicable. If necessary refer to the *Edited manuscript*.
- The publication of inaccurate data such as dosages and units can have serious consequences. Please take particular care that all such details are correct.
- Please **do not** make changes that involve only matters of style. We have generally introduced forms that follow the journal's style. Substantial changes in content, e.g., new results, corrected values, title and authorship are not allowed without the approval of the responsible editor. In such a case, please contact the Editorial Office and return his/her consent together with the proof.
- If we do not receive your corrections **within 48 hours**, we will send you a reminder.
- Your article will be published **Online First** approximately one week after receipt of your corrected proofs. This is the **official first publication** citable with the DOI. **Further changes are, therefore, not possible.**
- The **printed version** will follow in a forthcoming issue.

Please note

After online publication, subscribers (personal/institutional) to this journal will have access to the complete article via the DOI using the URL: [http://dx.doi.org/\[DOI\]](http://dx.doi.org/[DOI]).

If you would like to know when your article has been published online, take advantage of our free alert service. For registration and further information go to: <http://www.link.springer.com>.

Due to the electronic nature of the procedure, the manuscript and the original figures will only be returned to you on special request. When you return your corrections, please inform us if you would like to have these documents returned.

Metadata of the article that will be visualized in OnlineFirst

ArticleTitle	Problem-based projects in medical education: extending PBL practices and broadening learning perspectives	
--------------	---	--

Article Sub-Title		
-------------------	--	--

Article CopyRight	Springer Nature B.V. (This will be the copyright line in the final PDF)	
-------------------	--	--

Journal Name	Advances in Health Sciences Education	
--------------	---------------------------------------	--

Corresponding Author	Family Name	Stentoft
	Particle	
	Given Name	Diana
	Suffix	
	Division	Centre for Health Science Education and Problem-Based Learning
	Organization	Aalborg University
	Address	Fredrik Bajers Vej 7D, 9220, Ålborg, Denmark
	Phone	+45 9940 9783
	Fax	
	Email	stentoft@hst.aau.dk

Schedule	Received	9 April 2019
	Revised	
	Accepted	31 August 2019

Abstract	<p>Medical education strives to foster effective education of medical students despite an ever-changing landscape in medicine. This article explores the utility of projects in problem-based learning—<i>project-PBL</i>—as a way to supplement traditional case-PBL. First, project-PBL may enhance student engagement and motivation by allowing them to direct their own learning. Second, project-PBL may help students develop metacognitive competencies by forcing them to collaborate and regulate learning in settings without a facilitator. Finally, project-PBL may foster skills and competencies related to medical research. As illustrated through a brief example from Aalborg University, Denmark, students learn differently from project-PBL and case-PBL, and so one implementation cannot simply replace the other. I conclude by suggesting future directions for research on project-PBL to explore its benefits in medical education.</p>	
----------	---	--

Keywords (separated by '-')	Active learning - Case-PBL - PBL - Problem-based learning - Projects - Project-PBL - Student-centred learning	
-----------------------------	---	--

Footnote Information		
----------------------	--	--



1 Problem-based projects in medical education: extending PBL 2 practices and broadening learning perspectives

3 Diana Stentoft¹

4 Received: 9 April 2019 / Accepted: 31 August 2019
5 © Springer Nature B.V. 2019

6 Abstract

7 Medical education strives to foster effective education of medical students despite an ever-
8 changing landscape in medicine. This article explores the utility of projects in problem-
9 based learning—*project-PBL*—as a way to supplement traditional case-PBL. First, project-
10 PBL may enhance student engagement and motivation by allowing them to direct their own
11 learning. Second, project-PBL may help students develop metacognitive competencies by
12 forcing them to collaborate and regulate learning in settings without a facilitator. Finally,
13 project-PBL may foster skills and competencies related to medical research. As illustrated
14 through a brief example from Aalborg University, Denmark, students learn differently from
15 project-PBL and case-PBL, and so one implementation cannot simply replace the other. I
16 conclude by suggesting future directions for research on project-PBL to explore its benefits
17 in medical education.

18 **Keywords** Active learning · Case-PBL · PBL · Problem-based learning · Projects · Project-
19 PBL · Student-centred learning

20 Introduction

21 In 2019 we celebrate 50 years of problem-based learning (PBL) in medical education:
22 50 years of putting students first in the learning process, and 50 years of making patients
23 the primary learning resource. It also marks an apt time to review what PBL has contrib-
24 uted to medical education, and how various implementations of PBL have changed the way
25 medical competencies are developed.

26 Such reflections on PBL are not new. More than 30 years ago, Howard Barrows outlined
27 a taxonomy to explore the many possible forms of PBL and how they promote different
28 learning objectives (Barrows 1986). This taxonomy focused on several variables to cat-
29 egorize a given instantiation of PBL, including the structuring of problems and whether
30 learning is student- or teacher-directed. Since then, other authors have similarly created
31 taxonomies to categorize implementations of PBL according to key variables related to

A1 ✉ Diana Stentoft
A2 stentoft@hst.aau.dk

A3 ¹ Centre for Health Science Education and Problem-Based Learning, Aalborg University, Fredrik
A4 Bajers Vej 7D, 9220 Ålborg, Denmark

32 student engagement, teacher engagement, and the nature of problems (e.g. Savery 2006;
33 Savin-Baden 2014). These taxonomies all share the view that PBL is tied to narrow learn-
34 ing objectives where teachers and facilitators delimit the scope of learning through specific
35 case materials and prescribed learning steps. However, PBL can be more than this.

36 By closely examining the birth of PBL across four leading PBL universities around the
37 world, Servant (2016) found that PBL emerged by two distinct means. On one hand, in
38 medical schools at McMaster University and Maastricht University, PBL was organized
39 around patient cases developed by teachers, and students learned through well-constructed
40 steps. In sharp contrast, at Aalborg University and Roskilde University, PBL emerged
41 around the same time, but was organized around open-ended and student-centred pro-
42 jects running over extensive periods of time and supported by project supervisors. For
43 consistency, I will hereafter refer to these two strategies as case-PBL and project-PBL,
44 respectively.

45 After 50 years of PBL predominantly centred around patient cases in medical educa-
46 tion, it is perhaps time to re-examine the merits of project-PBL. This re-examination is
47 timely, especially because of changing demographics and aging populations, access to vast
48 amounts of information, and increasing pressure placed on health care systems.

49 Little research has discussed the challenges and implications of project-PBL as a means
50 to complement case-PBL or other traditional approaches in medical education. The present
51 paper sparks this discussion by exploring how project-PBL differs substantially from case-
52 PBL. To further elucidate how project-PBL may be integrated into undergraduate medical
53 curricula, an implementation at the medical school of Aalborg University in Denmark is
54 presented. The paper concludes with a brief discussion of further research that aims to
55 shift project-PBL from the status of innovative practice into an evidence-based approach,
56 fostering the development of new competencies. As these points are elaborated below, it is
57 important to note that project-PBL is not being proposed as an alternative to case-PBL, but
58 instead as an innovative approach that may foster supplementary skills and competencies,
59 especially those pertaining to research.

60 PBL as cases and projects

61 Project-PBL and case-PBL are both founded upon similar theoretical principles about
62 learning. Problems are seen as the entry point to the learning process, student collabora-
63 tion is thought to enhance learning, teaching is organized as facilitation and supervision,
64 and students are required to take responsibility for their own learning (Barrett and Moore
65 2011; Barrows 1996; Davis and Harden 1999; Hmelo 2004; Laursen 2013; Savery 2006;
66 Savin-Baden and Major 2004; Schmidt 1983). Similarly, both approaches to PBL are based
67 on assumptions about students being active, self-directed, and bringing their prior experi-
68 ences into the learning process. Thus, as noted by Barrows (1986), PBL addresses learning
69 objectives that are often not addressed in more conventional approaches. These objectives
70 include the structuring of knowledge and reasoning, learning to be self-directed, and refin-
71 ing an understanding of learning needs or motivations.

72 Therefore, it is not theoretical assumptions about learning that distinguish project-PBL
73 from case-PBL, but rather learning objectives and the nature of problems with which stu-
74 dents learn. Project-PBL is aimed at students reaching learning objectives stated in abstract
75 and open terms, often inviting students to work in interdisciplinary learning spaces (Stentoft
76 2017). This means learning objectives in project-PBL can focus on theoretical as well as
77 methodological aspects of medical research. Hence, projects typically do not include detailed

AQ1

78 descriptions of activities because the broad learning objectives must be defined by the students
79 themselves in collaboration with their project supervisor. In contrast, learning objectives in
80 case-PBL are typically defined much more narrowly; for example, with respect to a specific
81 organ system, patient group, or disease (MacDonald 1997). Hence, in case-PBL, specific sce-
82 narios or patient stories are created using carefully designed ‘problem triggers’ to ensure stu-
83 dents can reach prespecified learning objectives in a structured manner, normally assisted by a
84 facilitator (Wood 2003; Gijsselaers 1996).

85 Addressing further distinctions between project-PBL and case-PBL, Kolmos (2009) and
86 Helle et al. (2006) point to several variables that differ between the two approaches. These are
87 especially related to the scope of problems and the time spend on each problem. For example,
88 projects in project-PBL are open ended, leaving it up to students in collaboration with their
89 project supervisor to identify, justify, and define the problem they are working on, and to pre-
90 sent a rationale for the scientific relevance of the problem (Thorndahl et al. 2018). Projects are
91 typically carried out over an extended period in which students coordinate their projects in
92 collaboration with their supervisors (Holgaard et al. 2014). On the contrary, in case-PBL, case
93 materials developed by teachers delimit the spaces within which students can locate the prob-
94 lems to be addressed, and thus the scope of any case is intended to fully frame what students
95 will learn. The period for working with a case is often limited to one week and pre-defined
96 steps are followed.

97 The two approaches also differ in terms of assessment. For case-PBL, students strive
98 towards the shared goal of delivering a written product. Working with cases offers students a
99 unique experience to learn from peers while using prior experiences to construct new knowl-
100 edge. But students usually are not working towards any shared goal or written product. This is
101 reflected in the step often referred to as ‘private study time’ that occurs between cases (David
102 et al. 1999; Dolmans and Schmidt 2010). For project-PBL, however, students strive towards
103 the shared goal of delivering a written product. To ensure fairness, group exams are often used
104 however each individual student is assessed on their performance in relation to learning objec-
105 tives originally set out for the project. So although the joint written project forms the basis for
106 discussions, it is the responses of each student that determines their final grade. A study by
107 Kolmos and Holgaard (2007) suggests that such group-based exams assess students on com-
108 plex knowledge, but also helps them reflect on their scientific work and the team processes.
109 This way of assessing students is also aligned with a study on collaborative assessment, which
110 pointed to the importance of clarity in expected learning outcomes and opportunities for each
111 student to demonstrate their learning (Elliot et al. 2012).

112 Table 1 summarizes the key characteristics of project-PBL and case-PBL discussed thus
113 far. The two approaches clearly differ in many important aspects. In general, the practices of
114 project-PBL and case-PBL differ significantly, with the former arguably affording students
115 more autonomy and control over their own learning (de Graff and Kolmos 2003). It would
116 therefore be unreasonable to assume that students could gain the same knowledge, skills, and
117 competencies from either approach. This will be discussed further. However, now we will
118 move from abstract descriptions to the actual practice of project-PBL in medical education.
119 We will do this through a brief description of project-PBL as it unfolds at the medical school
120 of Aalborg University, Denmark.

Table 1 Comparison of case and project PBL in medical education

	Case PBL	Project PBL
Duration of PBL activity	1 week	Up to one entire semester
Learning objectives	Narrow aimed at students developing specific skills or acquiring specific knowledge	Broad aiming at students developing skills and competencies to explore scientific problems
Learning outcome	Clinical reasoning and knowledge acquisition	
Framing the problem	Through cases constructed by teachers	Through students defining a specific scientific problem from a broader theme
Role of students	Active during pre-scheduled case sessions and during activities and group meetings supporting the case learning	Organising the learning process, group meetings, meetings with supervisor, experiments and other activities required to address the problem defined
Role of facilitators	Facilitating learning during prescheduled case sessions	Facilitating and supervising learning when requested by the project group during the project period
End product	Individual or group notes to the extent that students find this useful	Written project report for which the entire group is responsible
Assessment	Individual through written or oral exams	Individual assessment based on shared written report and performance at group-based oral defence of the report

121 Integrating both project-PBL and case-PBL into medical education: Aalborg 122 University as an example

123 Aalborg University was founded in 1974 as a new Danish university. From the outset, the
124 university adopted project-PBL as an institutional approach to learning. PBL was regarded
125 as a way of realising a constructivist and student-centred vision for learning, inspired by
126 such prominent thinkers as John Dewey, Jean Piaget, and Oscar Negt (Illeris 1974; Servant
127 2016). Though the educational context has changed considerably since its establishment,
128 Aalborg University remains a dedicated PBL university today. This is reflected in the uni-
129 versity aiming for approximately 50% of all student activity to be centred around project-
130 PBL work in most studies offered.

131 The principles of PBL at Aalborg University state that the problem is starting point for
132 learning, and that learning is a collaborative process anchored in student groups. The prin-
133 ciples further state how students are responsible for their own learning while being sup-
134 ported by one or more supervisors. It is also emphasized that problems must be exemplary
135 and scientific. Problems must therefore reflect situations realistic and authentic within an
136 academic field or relevant to a profession (Askehave et al. 2015; Kolmos et al. 2004). Just
137 as when the university was first established, the reason for sustaining PBL through projects
138 is to focus education on the future professions of students, and to promote metacognitive
139 skills by having students engage with authentic and complex problems. Thus, PBL is seen
140 as a strategy for enhancing student employability, focusing on the skills and competen-
141 cies necessary to bring science into professional contexts. This is reflected in competencies
142 such as the ability to be self-directed, to collaborate, and to initiate and organize learning
143 when encountering complex real-life problems (Askehave et al. 2015).

144 Consequently, use of PBL was taken as a given when Aalborg University was granted
145 a medical education program in 2006, and the real question was *which* implementation of
146 PBL would be best. Considerations of the advantages and disadvantages of both project-
147 PBL and case-PBL resulted in a 10-step case-PBL model, framed around implementations
148 at McMaster University and Maastricht University. During the six-year undergraduate pro-
149 gram, however, students also encounter project-PBL on five occasions, constituting a work-
150 load equivalent to approximately 1.33 years of study. For example, the first project occurs
151 in the second semester over three consecutive weeks and is set within the domain of public
152 health. The final project occurs in the final year of study over the course of an entire semes-
153 ter (half a year) and focuses on clinical research (AAU 2017, 2018). Through such projects,
154 students encounter open and complex problems related to various fields in medicine and
155 medical research. The intention is to offer students a chance to practice transferring their
156 knowledge to new settings (Laursen 2013), to develop skills in core medical disciplines,
157 and to manage projects that resemble to real medical research. To deliver their written
158 reports, students must collaborate in groups of up to eight peers, and are expected to handle
159 knowledge gaps and overcome obstacles during the project period. Groups are allocated a
160 project supervisor with expertise in their field of medical research, but the responsibility
161 for making use of supervision in the most effective way is shared by the group. Figure 1
162 below presents a journey resulting from project-PBL.

163 To make Fig. 1 more concrete, here I provide an example of a project delivered at the
164 end of the third year. In collaboration with their supervisors, one of whom specialize in
165 clinical pain research and consult on sport-related injuries, a project group of 4 students
166 set out to examine the effects of running on pain perception. In their project the group first
167 present the background for their interest in the field of running and pain, then formulate

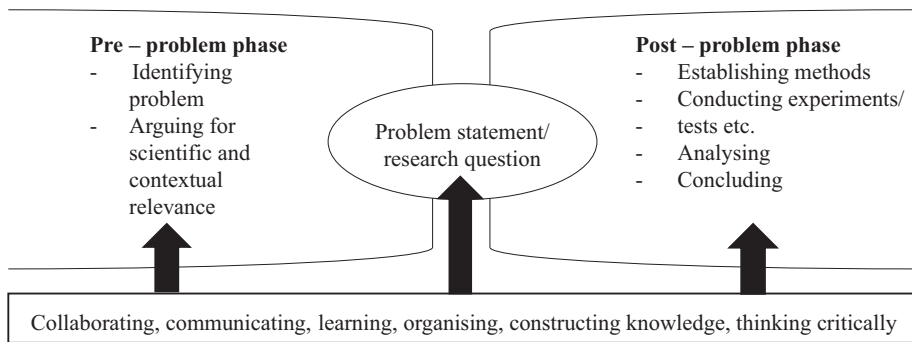


Fig. 1 A model of the problem-based project process in medical education

168 an argument as to why the perception of pain might decrease after a 5-km run. Based on
 169 their work the project group eventually construct the following problem statement, which
 170 they subsequently address in the post-problem phase of the project through experiments
 171 and tests. “The aim of this study was to investigate whether the pain perception will be
 172 decreased after a run of 5 km for healthy individuals in the age group 18–30 years.”
 173 (Schreiner et al. 2018, p. 10). This project allows students to use medical problems to
 174 acquire new knowledge, which was one of the broad learning objectives stated in the cur-
 175 rriculum. Other learning objectives related to the third year project specified how students
 176 must argue for a choice of scientific methods, assess results and hypotheses, then present
 177 project findings. Moreover, the learning objectives state that students must demonstrate the
 178 competencies to collaborate, to organize projects addressing complex medical problems,
 179 and to work with empirical research (AAU 2017). Student assessment was based on the
 180 group written report and via the oral examination. Grades were individual based on each
 181 students’ performance at the oral exam. To ensure high-quality assessment, an external
 182 examiner from another medical school in Denmark partook in the assessments.

183 **The role of projects in medical education**

184 How does project-PBL add value to the medical curriculum? Potential benefits of project-
 185 PBL will be discussed below. However, it is first important to note that for project-PBL to
 186 function properly, there must exist sufficient scaffolding of learning, active students, and
 187 supervisors willing to trust students to organize learning without a pre-set schedule (Kol-
 188 mos et al. 2008). In project-PBL it is not possible for students to skip class and simply
 189 prepare prior to exams. Students must instead be engaged throughout the entire process—
 190 otherwise there will be no final project to deliver for assessment!

191 If these prerequisites are met, one potential benefit of project-PBL is that students may
 192 be more motivated. Both project-PBL and case-PBL were found to motivate students
 193 at Aalborg University, but students clearly found projects more motivating than cases
 194 (Stentoft et al. 2014). This is consistent with research from Maastricht University suggest-
 195 ing benefits of progressively more self-directed learning to combat “PBL fatigue” among
 196 students working exclusively with cases (Czabanowska et al. 2012; Moust et al. 2005).
 197 Moust and Roebertsen (2010) further suggest implementation of PBL can gradually move
 198 towards projects in order for students to control their learning, collaboration and organisa-
 199 tion independently and thus develop skills as lifelong learners. Such meta-cognitive skills

200 (i.e., knowing how to best learn) are paramount to success in the complex and chaotic clinical setting beyond undergraduate medical education (Berkhout et al. 2018).

202 The ability to self-regulate learning processes has also been shown to predict student performance. How supervisors support students as self-regulated learners is thought to be critical (English and Kitsantas 2013).

205 For both project-PBL and case-PBL, student motivation is assumed to be derived from autonomy of learning, which naturally is greater when students assume responsibility for their own learning. This was reported in a study that compared student experiences of autonomy between project-PBL and case-PBL. The study found no difference student motivation, but students in project-PBL perceived their learning environment as more supportive of autonomy, and it was suggested that this occurred because problems in project-PBL appeared more authentic due to them being broader and lacking a single correct answer (Stefanou et al. 2013). In project-PBL, student autonomy is especially visible in the use of more open-ended projects towards the end of one's studies. This line of thinking is well aligned with Self Determination Theory first presented by Deci and Ryan (2002), which contends that intrinsic motivation relies on notions of autonomy, competence, and relatedness. Though project-PBL may offer more autonomy and greater relatedness through student collaboration, students are also more likely to feel a more incompetent during projects than when working with cases, because cases are narrower in scope and thus students are less likely to stray into unfamiliar new disciplines. This underpins how project- and case-PBL may offer quite different learning spaces.

221 As indicated above, whether using project-PBL or case-PBL, meta-cognitive competencies are often cited as a goal of education, and emphasizing these competencies has sparked debate. With the introduction of case-PBL, issues of ensuring that medical students leave university with the essential medical knowledge came to permeate educational debates because less time and resources are devoted to well-structured lectures and laboratory work, instead encouraging students to reflect and define their own learning needs. This caused concerns that PBL may be superficial and that students will lack comprehension of basic sciences (Lyon 2009). In contrast to this view, Lyon has suggested that PBL in medical education invites students to be critical thinkers; to explore the boundaries, scopes, and limitations of medical knowledge. However, this can only be realised insofar as the problems are sufficiently ill-defined and students are supported in exploring uncertain grounds (Barrett et al. 2011; Lyon 2009; Lähteenmäki and Uhlin 2011). Project-PBL speaks to this issue because it requires students to identify for themselves the problem from which they will learn about medicine, and in collaboration with supervisors, they develop not only new ways of thinking but a shared written product.

236 Interestingly, a study by Galand et al. (2012) compared a mixed case-PBL and project-PBL implementation to a conventional engineering education and found that the mixed PBL approach elicited superior acquisition and application of knowledge. This is interesting given that research into the effects of case-PBL alone has yielded varied results in terms of knowledge acquisition. Thus, the study suggests that project-PBL may foster competencies not only relevant to learning basic sciences, but also to applying knowledge to complex problems. This is also consistent with the idea that project-PBL resembles some of the roles and associated competencies (e.g., as communicator, collaborator, researcher) on which medical students will eventually be assessed when moving into postgraduate medical education (e.g. Frank et al. 2015; Sundhedsstyrelsen 2013). In this sense, it can be argued that supplementing case-PBL with project-PBL allows students to extend the range and scope of their learning, helping them apply their medical knowledge to increasingly complex situations.

249 As mentioned above, one main intention of integrating project-PBL into medical edu-
250 cation is to ensure students develop research competencies that are needed in their future
251 professions. In a systematic review and meta-analysis of medical students' participation in
252 research, it was found that students taking part in research exhibited greater scientific pro-
253 ductivity and interest in research. The study further indicated that there is a need to stand-
254 ardize the research process in medical education so that students are involved in the entire
255 research process, including the development of methodologies and data analysis. However,
256 it was also found that student research cannot be automatically assumed to lead to students
257 authoring scientific publications (Amgad et al. 2015). Project-PBL may offer such a stand-
258 ardized approach for integrating research skills and competencies into the medical curricu-
259 lum via research projects. But it is also essential to note that this requires resources and the
260 availability of researchers who are committed to work with students (Laidlaw et al. 2012).

261 A final potential benefit of project-PBL in medical education is related to the problem
262 itself. When using case-PBL, the underlying intentions are characterized as students either
263 acquiring knowledge of basic sciences, or developing clinical reasoning skills relevant to
264 diagnosing and treating patients. This is reflected in the problems being created by plan-
265 ners and facilitators to ensure students move along a specific learning trajectory (Charlin
266 et al. 1998). The intentions behind project-PBL are somewhat different. This is reflected
267 in learning objectives focused not simply on knowledge acquisition, but also on methods
268 and skills necessary to carry out scientific experiments, as well as competencies to apply,
269 analyse, evaluate, and synthesize results. That is, the open-ended nature of project-PBL is
270 intended to push students towards evaluating and synthesising across disciplinary domains,
271 and hence to navigate the qualitative part of the SOLO taxonomy. Project-PBL thus sup-
272 ports the development of competencies to organize research and to manage the path
273 towards completion of an entire cycle of research (de Graff and Kolmos 2003). Here, focus
274 is on thinking beyond disciplinary boundaries, and evaluating and synthesizing knowledge
275 into a new whole (Biggs and Tang 2009).

276 Although project-PBL may offer new perspectives and opportunities in medical educa-
277 tion, the uncovering of its potentials and pitfalls has only just begun. Project-PBL and case-
278 PBL differ significantly; not just in organization, but also in putative learning outcomes
279 for medical students. These differences should be considered carefully before introducing
280 projects into the curriculum. Critically, it has been suggested that introducing projects in
281 the later stages of medical education could mitigate PBL-fatigue and a slow erosion of
282 the PBL curriculum (Czabanowska, et al. 2012; Moust and Roebertsen 2010; Moust et al.
283 2005). Even if this is indeed the case, it requires a change of mindset regarding what it
284 means for medical students to learn, and how they are expected to navigate knowledge,
285 skills, and competencies at the end of their undergraduate education. These considerations
286 raise the issue of project-PBL being sensitive to organizational challenges and student
287 attitudes. Orchestrating collaborative research in project groups over weeks and months
288 requires both commitment and stamina for students and supervisors. Students must tackle
289 conflict and scientific disagreements, and supervisors must be willing to commit them-
290 selves to supporting the group while not controlling the work process. For many supervi-
291 sors, this relinquishing of power and control can be uncomfortable, and for some an insur-
292 mountable barrier to fulfilling the role of supervisor (Savin-Baden and Major 2004).

293 I reiterate that research on the effectiveness of project-PBL in higher education is almost
294 non-existent, making it difficult to conduct systematic reviews or other forms of knowledge
295 synthesis (Galand et al. 2012). One possible reason for this lack of research is the complex
296 and student-driven nature of project-PBL. Namely, work in project-PBL is organized by
297 students over long periods of time, and at locations—both physical and digital—beyond

298 the direct observations of supervisors and researchers. There is therefore a dire need to
299 develop new research methodologies if such dynamic learning processes are to be under-
300 stood. Specifically, research must be done to examine whether project-PBL promotes the
301 specific research competencies in medicine, and whether supplementing case-PBL with
302 project-PBL enhances metacognitive skills in medical students that affect their entry into
303 clinical practice.

304 Conclusion

305 In this article, project-PBL is proposed as a pedagogical innovation. I argue that project-
306 PBL in medical education broadens student metacognitive competencies and foster skills
307 relevant to medical problems and research. I also emphasize that project-PBL should not
308 be seen as a competitor or alternative to traditional case-PBL, but rather a timely supple-
309 ment to produce well-rounded doctors.

310 References

- 311 AAU. (2017). *Curriculum for B.sc. in medicine faculty of medicine*. Aalborg University. <https://studieordn.inger.aau.dk/2019/14/780>.
- 312
- 313 AAU. (2018). *Curriculum for M.sc. in medicine: faculty of medicine*. Aalborg University. <https://studieordn.inger.aau.dk/2019/17/901>.
- 314
- 315 Amgad, M., Tsui, M. M. K., Liptrott, S. J., & Shash, E. (2015). Medical student research: An integrated
316 mixed-methods systematic review and meta-analysis. *PLoS ONE*, *10*(6), e0127470.
- 317 Askehav, I., Prehn, H., Pedersen, J., & Pedersen, M. T. (2015). *PBL—Problem-based learning Aalborg*.
318 Denmark: Aalborg University.
- 319 Barrett, T., Cashman, D., & Moore, S. (2011). Designing problems and triggers in different media. In T.
320 Barrett & S. Moore (Eds.), *New approaches to problem-based learning revitalising your practice in*
321 *higher education* (pp. 18–35). New York: Routledge.
- 322 Barrett, T., & Moore, S. (2011). An introduction to problem-based learning. In T. Barrett & S. Moore
323 (Eds.), *New approaches to problem-based learning revitalising your practice in higher education* (pp.
324 3–17). New York: Routledge.
- 325 Barrows, H. S. (1986). A taxonomy of problem-based learning methods. *Medical Education*, *20*(6),
326 481–486.
- 327 Barrows, H. S. (1996). Problem-based learning in medicine and beyond: a brief overview. *New Directions*
328 *for Teaching and Learning*, *68*, 3–12.
- 329 Berkhout, J., Helmich, E., Teunissen, P., van der Vleuten, C. P. M., & Jaarsma, A. D. C. (2018). Context
330 matters when striving to promote active and lifelong learning in medical education. *Medical Educa-*
331 *tion*, *52*, 34–44.
- 332 Biggs, J., & Tang, C. (2009). *Teaching for quality learning at university* (3rd ed.). Maidenhead: Society for
333 Research into Higher Education & Open University Press.
- 334 Charlin, B., Mann, K., & Hansen, P. (1998). The many faces of problem-based learning: A framework for
335 understanding and comparison. *Medical Teacher*, *20*(4), 323–330.
- 336 Czabanowska, K., Moust, J. H. C., Meijer, A. W. M., Schröder-Bäck, P., & Roebertsen, H. (2012). Problem-
337 based learning revisited, introduction of active and self-directed learning to reduce fatigue among stu-
338 dents. *Journal of University Teaching & Learning Practice*, *9*(1), 1–13.
- 339 David, T., Patel, L., Burdett, K., & Rangachari, P. (1999). *Problem-based learning in medicine*. London:
340 The Royal Society of Medicine Press Limited.
- 341 Davis, M. H., & Harden, A. (1999). AMEE Medical education guide no 15: Problem-based learning—A
342 practical guide. *Medical Teacher*, *21*(2), 130–140.
- 343 Deci, E. L., & Ryan, R. M. (2002). *Handbook of self-determination research*. Rochester: University of
344 Rochester Press.
- 345 de Graff, E., & Kolmos, A. (2003). Characteristics of problem-based learning. *International Journal of*
346 *Engineering Education*, *5*(19), 657–662.

- 347 Dolmans, D., & Schmidt, H. (2010). The problem-based learning process. In H. van Berkel, A. Scherpbier,
348 H. Hillen, & C. van der Vleuten (Eds.), *Lessons from problem-based learning* (pp. 13–18). Oxford:
349 Oxford University Press.
- 350 Elliot, M., Howard, P., Nouwens, F., Stojcevski, A., Mann, L., Prpic, J. K., et al. (2012). Developing a concep-
351 tual model for the effective assessment of individual student learning in team-based subjects. *Aus-
352 tralasian Journal of Engineering Education*, 18(1), 105–112.
- 353 English, M. C., & Kitsantas, A. (2013). Supporting student self-regulated learning in problem- and project-
354 based learning. *Interdisciplinary Journal of Problem-Based Learning*, 7(2), 128–150.
- 355 Frank, J. R., Snell, L., & Scherbino, J. (Eds.). (2015). *CanMEDS 2015: Physician competency framework*.
356 Ottawa: Royal College of Physicians and Surgeons of Canada.
- 357 Galand, B., Frenay, M., & Raucent, B. (2012). Effectiveness of problem-based learning in engineering edu-
358 cation: A comparative study on three levels of knowledge structure. *International Journal of Engineer-
359 ing Education*, 28(4), 939–947.
- 360 Gijsselaers, W. H. (1996). Connecting problem-based practices with educational theory. In L. Wilkerson &
361 W. H. Gijsselaers (Eds.), *Bringing problem-based learning to higher education: Theory and practice*.
362 San Francisco: Jossey-Bass.
- 363 Helle, L., Tynjälä, P., & Olkinuora, E. (2006). Project-based learning in post-secondary education: Theory
364 practice and rubber sling shots. *Higher Education*, 51(2), 287–314.
- 365 Hmelo, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology
366 Review*, 16(3), 235–266.
- 367 Holgaard, J. E., Rybert, T., Stegeager, N., Stentoft, D., & Thomassen, A. O. (2014). *PBL: Problembaseret
368 læring og projektarbejde ved de videregående uddannelser*. Copenhagen: Samfundslitteratur.
- 369 Illeris, K. (1974). *Problemorientering og deltagerstyring: oplæg til en alternativ didaktik*. Odense: Fyens
370 Stiftsbogtrykkeri.
- 371 Kolmos, A. (2009). Problem-based and project-based learning. In O. Skovmose, P. Valero, & O. Ravn
372 Christensen (Eds.), *University science and mathematics education in transition* (1st edn ed., pp. 261–
373 280). New York: Springer.
- 374 Kolmos, A., Du, X., Holgaard, J. E., & Jensen, L. P. (2008). *Facilitation in a PBL environment*. Aalborg:
375 Publication for Centre for Engineering Education Research and Development.
- 376 Kolmos, A., Fink, F. K., & Krogh, L. (2004). The Aalborg model: Problem-based and project-organized
377 learning. In A. Kolmos, F. K. Fink, & L. Krogh (Eds.), *The Aalborg PBL model* (1st ed., pp. 9–18).
378 Aalborg: Aalborg University Press.
- 379 Kolmos, A., & Holgaard, J. E. (2007). Alignment of PBL and assessment. *Journal of Engineering Educa-
380 tion*, 96(4), 1–9.
- 381 Lähteenmäki, M., & Uhlin, L. (2011). Developing reflective practitioners through pbl in academic and prac-
382 tice environments. In T. Barrett & S. Moore (Eds.), *New approaches to problem-based learning re-
383 vitalising your practice in higher education* (pp. 144–157). New York: Routledge.
- 384 Laidlaw, A., Aiton, J., Struthers, J., & Guild, S. (2012). Developing research skills in medical students:
385 AMEE Guide no. 69. *Medical Teacher*, 34(9), 754–771.
- 386 Laursen, E. (2013). PPBL: A flexible model addressing the problems of transfer. In L. Krogh & A. A.
387 Jensen (Eds.), *Visions challenges and strategies: PBL principles and methodologies in a Danish and
388 global perspective* (pp. 29–46). Aalborg: Aalborg University Press.
- 389 Lyon, M. L. (2009). Epistemology, medical science and problem-based learning: intruding an epistemolo-
390 gical dimension into the medical-school curriculum. In C. Brosnan & B. S. Turner (Eds.), *Handbook
391 of the sociology of medical education* (pp. 207–224). Oxon: Routledge.
- 392 MacDonald, P. J. (1997). Selection of health problems for a problem-based curriculum. In D. Boud & G.
393 Feletti (Eds.), *The challenge of problem-based learning* (2nd ed., pp. 93–102). New York: Routledge.
- 394 Moust, J., & Roebertsen, H. (2010). Alternative instructional problem-based learning formats. In H. van
395 Berkel, A. Scherpbier, H. Hillen, & C. van der Vleuten (Eds.), *Lessons from problem-based learning*
396 (pp. 129–140). Oxford: Oxford University Press.
- 397 Moust, J., Van Berkel, H. J. M., & Schmidt, H. G. (2005). Signs of erosion: Reflections on three decades of
398 problem-based learning at Maastricht University. *Higher Education*, 50, 665–683.
- 399 Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. *The Interdiscipli-
400 nary Journal of Problem-Based Learning*, 1(1), 9–20.
- 401 Savin-Baden, M. (2014). Using problem-based learning: New constellations for the 21st century. *Journal on
402 Excellence in College Teaching*, 25(3&4), 1–24.
- 403 Savin-Baden, M., & Major, C. H. (2004). *Foundations of problem based learning* (p. 2004). Buckingham:
404 Society for Research into Higher Education & Open University Press.
- 405 Schmidt, H. G. (1983). Problem-based learning: Rationale and description. *Medical Education*, 17(1),
406 11–16.

Problem-based projects in medical education: extending PBL...

- 407 Schreiner, M. P., Bruun, S. R., Liljeborg, C. K., & Svendsen, J. L. (2018). *The effect of run on pain perception—B.sc. medicine 6th semester*. Aalborg: Aalborg University.
- 408
- 409 Servant, V. F. C. (2016). *Revolutions and re-iterations*. Riddekerk: Ridderprint BV.
- 410 Stefanou, C., Stolk, J. D., Prince, M., Chen, J. C., & Lord, S. M. (2013). Self-regulation and autonomy
411 in problem- and project-based learning environments. *Active Learning in Higher Education*, 14(2),
412 109–122.
- 413 Stentoft, D. (2017). From saying to doing interdisciplinary learning—Is PBL the answer? *Active Learning
414 in Higher Education*, 18(1), 51–61.
- 415 Stentoft, D., Duroux, M., Fink, T., & Emmersen, J. (2014). From cases to projects in problem-based medical
416 education. *Journal of Problem Based Learning in Higher Education*, 2(1), 45–62.
- 417 Sundhedsstyrelsen. (2013). *De 7 Lægeroller*. www.sst.dk Sundhedsstyrelsen.
- 418 Thorndahl, K., Velmurugan, G. & Stentoft, D. (2018) The significance of problem analysis for critical think-
419 ing in problem-based project work. In Sunyu, W., Kolmos, A., Guerra, A., & Weifeng, Q. (Eds.). *7th
420 International research symposium on PBL: innovation, PBL and competences in engineering educa-
421 tion*. Aalborg: Aalborg Universitetsforlag.
- 422 Wood, D. F. (2003). ABC of learning and teaching in medicine—Problem based learning. *British Medical
423 Journal*, 326, 328–330.

424 **Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and
425 institutional affiliations.

426

Journal: 10459
Article: 9917

Author Query Form

Please ensure you fill out your response to the queries raised below and return this form along with your corrections

Dear Author

During the process of typesetting your article, the following queries have arisen. Please check your typeset proof carefully against the queries listed below and mark the necessary changes either directly on the proof/online grid or in the 'Author's response' area provided below

Query	Details Required	Author's Response
AQ1	Please check and confirm the section headings are correctly identified.	