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Please cite this paper as:

Hoidn, S. and K. Kärkkäinen (2014), "Promoting Skills for Innovation in Higher Education: A Literature Review on the Effectiveness of Problem-based Learning and of Teaching Behaviours", *OECD Education Working Papers*, No. 100, OECD Publishing.
http://dx.doi.org/10.1787/5k3tsj67l226-en



OECD Education Working Papers
No. 100

Promoting Skills for Innovation in Higher Education

A LITERATURE REVIEW ON THE EFFECTIVENESS OF PROBLEM-BASED LEARNING AND OF TEACHING BEHAVIOURS

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Unclassified **EDU/WKP(2013)15**

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development **16-Jan-2014**

English - Or. English

DIRECTORATE FOR EDUCATION AND SKILLS

EDU/WKP(2013)15
Unclassified

PROMOTING SKILLS FOR INNOVATION IN HIGHER EDUCATION: A LITERATURE REVIEW ON THE EFFECTIVENESS OF PROBLEM-BASED LEARNING AND OF TEACHING BEHAVIOURS

OECD Education Working Paper No. 100

Sabine Hoidn and Kiira Kärkkäinen

Higher education plays an important role in providing people with skills for innovation, but a number of important questions remain as to what kind of higher education teaching can be conducive to the strengthening of skills for innovation. This report aims to shed light on this issue by reviewing the current evidence on the effectiveness of problem-based learning compared with more traditional approaches in higher education teaching. It explores the extent to which problem-based learning can be an effective way to develop different discipline-specific and transferable skills for innovation. Research, primarily from the field of medicine, shows that problem-based learning appears to be beneficial in fostering certain aspects of skills for innovation. In addition, the report explores the literature on direct teaching behaviours that may help foster student learning in more traditional teaching settings. Despite the promising evidence linking problem-based learning and effective teaching in higher education to certain aspects of skills for innovation, more work is needed in this area. There is strong potential for further research to provide additional important insights into the development of skills for innovation.

The paper was prepared by Sabine Hoidn (Harvard University) and Kiira Kärkkäinen (formerly OECD Directorate for Education and Skills). It forms part of the CERI Innovation Strategy for Education and Skills.

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JT03351152

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SUMMARY

Future economic growth and social progress in knowledge societies rely increasingly on innovation. Innovators and entrepreneurs require skill sets for innovation such as technical skills, thinking and creativity skills, as well as social and behavioural skills. Higher education plays an important role in providing people with skills for innovation, but a number of important questions remain as to what kind of higher education teaching can be conducive to the strengthening of skills for innovation.

This report aims to shed light on this issue by reviewing the current evidence on the effectiveness of problem-based learning compared with more traditional approaches in higher education teaching. Problem-based learning typically requires students to work in small groups to solve real-world problems. The report explores the extent to which problem-based learning can be an effective way to develop different discipline-specific and transferable skills for innovation.

Research, primarily from the field of medicine, shows that problem-based learning appears to be beneficial in fostering long-term retention and knowledge application, developing thinking and creativity skills, as well as social and behavioural skills (e.g. problem-solving, critical thinking, motivation, self-confidence, team work). By contrast, no clear difference between problem-based learning and traditional lecture-based teaching emerges as to performance in tests.

In addition, the report explores the literature on direct teaching behaviours that may help foster student learning in more traditional teaching settings. Enhancing the effectiveness of direct forms of higher education teaching is a key challenge for many institutions, especially since problem-based learning is not feasible in all circumstances. A number of teaching attributes such as organisation, expressiveness, enthusiasm and rapport/interaction have been found to have a positive relationship with indicators of student learning and student persistence.

Despite the promising evidence linking problem-based learning and effective teaching in higher education to certain aspects of skills for innovation, more work is needed in this area. In reality there is no dichotomy between problem-based learning and "traditional" teaching and learning approaches – policymakers and practitioners would benefit from a better understanding about which specific practices are effective for fostering different skill sets. There is also scope to examine the impact of problem-based learning on a broader range of indicators of skills for innovation, and for the impact of contextual factors to be tested. There is therefore strong potential for further research to provide additional important insights into the development of skills for innovation.

RÉSUMÉ

À l'avenir, la croissance économique et le progrès social vont de plus en plus reposer sur l'innovation dans les sociétés de la connaissance. Les innovateurs et les entrepreneurs ont besoin de compétences pour l'innovation telles que des compétences techniques, des compétences de réflexion et de créativité, et des compétences sociales et comportementales. L'enseignement supérieur joue un rôle important pour développer ces compétences chez les gens mais il reste plusieurs questions concernant des approches pédagogiques qui peuvent conduire au renforcement des compétences pour l'innovation.

Le rapport vise à éclairer ce sujet en examinant des études récentes sur l'efficacité de l'enseignement par résolution de problèmes comparée à celle d'approches plus traditionnelles. L'enseignement par résolution de problèmes nécessite en général aux élèves de travailler en petits groupes pour résoudre des problèmes de la vie quotidienne. Le rapport explore dans quelle mesure l'enseignement par résolution de problèmes peut être un moyen efficace de développer différentes compétences disciplinaires spécifiques et transférables.

La littérature de recherche, principalement issu du domaine de la médicine, montre que l'apprentissage par résolution de problèmes apparaît comme bénéfique pour développer la rétention à long terme et pour le savoir appliqué, pour promouvoir les compétences de réflexion et de créativité, ainsi que pour les compétences sociales et comportementales (e.g. la résolution de problème, la réflexion critique, la motivation, la confiance en soi, le travail d'équipe). Par contre, on n'aperçoit pas une différence claire entre l'apprentissage par résolution de problèmes et l'enseignement traditionnel via des conférences en fonction des résultats des étudiants.

De plus, le rapport examine la littérature de recherche des stratégies d'enseignement qui peuvent aider à encourager l'apprentissage dans les contextes d'enseignement plus traditionnels. Améliorer l'efficacité des formes directes de l'enseignement est un défi majeur pour de nombreux établissements de l'enseignement supérieur, d'autant plus que l'enseignement par résolution de problèmes n'est pas réalisable dans tous les contextes. De nombreux stratégies d'enseignement telles que l'organisation, l'expressivité, l'enthousiasme et les rapports interactifs dans l'enseignement ont été trouvés à améliorer des indicateurs de l'apprentissage des étudiants et leur persistance.

Malgré les indications prometteuses reliant l'enseignement par résolution de problèmes et d'autres formes d'enseignement efficace à certains aspects de compétences pour l'innovation, plus de recherche est nécessaire dans ce domaine. En réalité, il n'y a pas de dichotomie entre l'enseignement par résolution de problèmes et des formes d'enseignement et d'apprentissage «traditionnelles» ; les décideurs et les professionnels bénéficieraient de connaître plus sur quelles pratiques spécifiques sont efficaces pour promouvoir des compétences différentes. Il est également possible d'examiner l'impact de l'enseignement par résolution de problèmes sur un plus large éventail d'indicateurs de compétences pour l'innovation, et pour l'impact des facteurs contextuels d'être testé. Le recherche additionnel a donc un fort potentiel de fournir des informations importantes sur le développement des compétences pour l'innovation.

INTRODUCTION

Future economic growth and social progress in knowledge societies rely increasingly on innovation[1]. An innovation is an idea, practice, or object that is perceived as new by a unit of adoption and carried out into practice (Rogers, 2003). It can be defined as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method" (OECD, 2007, p. 46). Innovation can be new to the world, a market, a sector – or to an organisation such as an enterprise or a school. In addition to radical, new-to-the-world inventions such as the Internet, the concept of innovation includes also incremental adaptation and gradual adoption in different contexts.

Innovation calls for a large number of – often highly educated – people equipped with diverse skills sets. It is increasingly acknowledged that future innovators and entrepreneurs will require a large range of skills to be able to meet the demands of the changing economy (OECD, 2010). A larger stock of people with strong innovation skills seems more likely to promote innovation than the converse. A broad range of skills in the workplace are in demand due to a structural shift towards services and knowledge-intensive jobs (Cedefop, 2010; European Commission, 2010). In addition to strong subject-based know-how, skills such as critical thinking, creativity, problem solving and ability to look at things from broad perspectives will be needed. People will need to work in teams, communicate their messages effectively and adapt to changing circumstances – interact with their environment instead of working in isolation. Both discipline-specific and more generic, transferable skills are crucial for today's students to be prepared for tomorrow's workplace (Barrett and Moore, 2011; Savery, 2006) and may be learnt in tandem. Indeed, the role of an "innovator" is not necessarily identical with the role of an "inventor" unless the invention of an idea and its application in practice come together (Fagerberg, 2005).

Overall, the following three overlapping sets of skills for innovation[2] – often referred to also as the "21st century" skills – can now be considered:

- Technical skills including disciplinary know-what and know-how. Innovative or creative people often require specialist skills in their field – both in terms of knowledge and methods.

- Thinking and creativity skills such as curiosity, critical thinking, problem solving and making connections. For example, creativity is generally seen to be an important source of innovation, whereas innovating often consists of connecting seemingly unrelated ideas also from different disciplines. Innovation tends to also require open-mindedness and critical questioning well established ideas or practices.

- Social and behavioural skills such as interest, engagement, self-directed learning, self-confidence, organisation, communication, (cross-cultural) collaboration, teamwork and leadership. For example, entrepreneurial competences such as self-confidence are important for initiating and carrying through an innovative project, as is the ability to plan and manage projects. Innovation tends to also require communication skills, including the ability to persuade others, as well as the ability to work with others in a team and coordinate activities – nowadays, in an increasingly international context. In addition of being a desired outcome in its own right, engagement plays a crucial role on study persistence and can be seen as a proxy for learning (see Pascarella and Terenzini, 1991, 2005; Nelson Laird, Chen and Kuh, 2008).

Box 1. Learning science perspectives

Learning sciences focus on learning and learners in addition to teaching and teachers. The goal is "to better understand the cognitive and social processes that result in the most effective learning, and to use this knowledge to redesign classrooms and other learning environments so that people learn more deeply and more effectively" (Sawyer, 2006, p. xi). It is suggested that students need to actively participate in their own learning in order to make sense of the world. Whilst a rich body of knowledge about subject matter is important to support understanding and transfer, this knowledge needs to be connected and organised around important concepts and conditionalised to specify the contexts in which it is applicable. This also leads to a focus on the processes of knowing – with learners bringing their prior knowledge to the learning setting and actively constructing knowledge based on what they already know and believe, including misconceptions. Students need to reflect upon their learning processes applying meta-cognitive strategies aligned with subject matter in order to learn more effectively (Barrows, 1985; Bransford, Brown and Cocking, 2000; Sawyer, 2006, 2008).

For deep learning to happen, cognitive processing of information and, as a result, a change in the learner's knowledge are necessary as one important component of cognition. In line with a cognitive constructivist view, Kirschner, Sweller and Clark (2006, pp. 76-78) building on theoretical knowledge about long-term and working memory argue that learners need to engage in cognitive activity in order to learn effectively:

- *Long-term memory* constitutes the dominant structure of human cognition and provides a huge information and knowledge base accumulated through prior experiences. Long-term memory is central in order to engage in cognitive activity. For example, compared to novices, experts draw on extensive experience stored in their long-term memory to solve problems, while novices lack proper schemas to integrate new information (Bransford, Brown and Cocking, 2000). Hence, learning – in this cognitive interpretation – occurs when the long-term memory is altered.

- *Working memory* is in charge of conscious information processing. It is limited in duration and capacity when novel information is processed. For example, information that is processed, but not rehearsed, can be lost within seconds. Only a limited number of elements can be processed or stored. Cognitive load theory suggests that discovery learning within a complex learning environment generates a heavy working memory load that is detrimental to learning (e.g. Paas, van Gog and Sweller, 2010). On the other hand, the limitations do not apply when familiar information that is already stored in long-term memory is brought back into working memory.

Broader social constructivist views on human cognition highlight the importance of context and process. They suggest that a cognitive architecture must "account for the context, the learner, and the processes of cognition (social and cognitive) in order to explain or predict cognitive activities" (Jonassen, 2009, p. 353). Learning does not only depend on cognitive processes but also on social interactions, participation in a community and other processes leading to a contemporary understanding of cognition as distributed and learning as essentially "contextualised" (Lave and Wenger, 1991; Duffy, 2009).

Yet, researchers disagree on how much and what kind of guidance is necessary for effective learning to take part. There are in essence two positions on whether more or less instructional guidance during teaching is effective regarding learning and student achievement (e.g. Hmelo-Silver, Duncan and Chinn, 2007; Kirschner, Sweller and Clark, 2006; Mayer, 2004)[3]:

- People learn – understand – best when they can discover and construct knowledge for themselves in an unguided or minimally guided environment (e.g. Bruner, 1961; Duckworth, 2006). In general, student-centred approaches such as discovery learning, problem-based learning, inquiry learning, experiential learning and constructivist learning account for such minimal direct guidance.

- (Novice) Learners should be provided with direct instructional guidance on the concepts and procedures required by a particular discipline. Direct instructional guidance means "providing information that fully explains the concepts and procedures that students are required to learn as well as learning strategy support that is compatible with human cognitive architecture." (Kirschner, Sweller and Clark, 2006, p. 75).

While higher education plays an important role in providing people with skills for innovation (European Commission, 2011), a challenge is to develop a variety of innovation skills simultaneously. Learning experiences focused on the demands of life and work in the 21st century are needed as "we are currently preparing students for jobs that do not yet exist, to use technologies that have not yet been invented, and to solve problems that we don't even know are problems yet" (Darling-Hammond, 2008, pp. 1-2). Yet, the theory-practice gap may exist in many disciplines such as management with graduates capabilities not necessarily meeting the needs of the professional life (e.g. Armstrong and Fukami, 2009; Bennis and O'Tool, 2005).

These high-level trends create a range of challenges for teaching in higher education. Partly in response, higher education institutions and the research community worldwide have put increased focus on more student-centred forms[4] of learning such as problem-based learning (PBL). Research on how people learn has laid the groundwork for new insights into learning and led to new approaches to curriculum, teaching and assessment. PBL, for example, is designed to develop transferable skills along with the appropriate discipline specific knowledge[5] that is learned in the same context in which it is used later on (Barrows, 1985; Bransford, Brown and Cocking, 2000; Donovan and Bransford, 2005). Overall, the emphasis on learning with understanding and active student participation can be seen as one of the hallmarks of the new learning sciences (Box 1).

Structure of the report

The remainder of this report examines what kind of higher education teaching could be conducive to strengthening skills for innovation. It focuses particularly on PBL, but also examines specific characteristics of more conventional teaching behaviours. Firstly, the report sets out some trends in and examples of teaching and learning models in higher education, as well as some government initiatives in OECD countries around teaching effectiveness. The following chapter examines the empirical evidence on how PBL may influence aspects of skills for innovation compared with more traditional models of teaching. The report then explores the evidence for how specific teaching behaviours may enhance the instructional effectiveness of direct (i.e. non-PBL) higher education teaching. The final chapter concludes and summarises the future research challenges in the area of PBL and higher education teaching effectiveness.

NOTES

[1] The beginning of innovation research/management traces back to Joseph Schumpeter's understanding of economic innovation (Schumpeter, 1934) .

[2] See OECD/CERI Innovation Strategy for Education and Training: www.oecd.org/edu/innovation.

[3] The article by Kirschner, Sweller and Clark (2006) sparked discussions and debates between both supporters and opponents of constructivist instruction (e.g. Schmidt, Loyens, van Gog & Paas, 2007; Hmelo-Silver, Duncan & Chinn, 2007; Kuhn, 2007; Sweller, Kirschner & Clark, 2007; Schmidt, Van der Molen, Te Winkel & Wijnen, 2009; Tobias & Duffy, 2009). The article argued that minimally guided problem-solving search "is an inefficient way of altering long-term memory because its function is to find a problem solution, not alter long-term memory" (p. 80).

[4] Common terms used for student-centred forms of learning are problem-based learning, discovery learning, experiential learning, cooperative learning, service learning or inquiry-based learning, for example (Justice, Rice, Roy & Hudspith, 2009).

[5] Thirty years of research suggest that generic skills such as problem-solving skills are learned together with subject matter knowledge, that is, problem-solving skills are domain-dependent and knowledge-based (e.g. Norman, 2005; Schmidt, Rotgans & Yew, 2011).

INCREASED FOCUS ON TEACHING AND LEARNING IN HIGHER EDUCATION

Focus on higher education teaching and learning is growing around the world, along with the recognition that future innovation, growth and social progress require skilled people. At the international level, the OECD Innovation Strategy[1], launched in 2010, highlights the essential role of diverse skills in innovation processes and the OECD Skills Strategy[2] of 2012 explores further the crucial issues of skills development (OECD, 2012). Also the European Commission (2010) promotes transversal key competencies for all citizens and advocates that European cooperation in education and training should include the objectives of creativity, innovation and entrepreneurship at all levels of education. Increasing focus on student-centred learning instead of teacher-driven provision can be also identified as a trend in Europe (Crosier, Purser and Smidt, 2007). Individual countries such as Australia and Ireland have formulated either national innovation strategies with a clear focus on skills or established specific skills strategies (Expert Group on Future Skills Needs, 2007; Commonwealth of Australia, 2009). In the United States, the New Commission on the Skills of the American Workforce[3] – assembling business, government, civil rights and education leaders – calls for changes in education and training systems as a response to the challenges of the 21st century (National Center on Education and the Economy, 2006). In the higher education research literature teaching and learning has gained more attention since the 1990s, covering a range of themes such as active learning, interdisciplinarity and quality of outcomes (Kezar, 1999; Kezar 2000).

In line with these developments, several higher education institutions around the world are aiming to train socially responsible future innovators, entrepreneurs and leaders. In the United States, Franklin W. Olin College was founded in 2002 to be an "engineering college of the new millennium"[4]. Complemented for the quality and engaging character of its education, the institution aims to train "technological leaders who are both creative and entrepreneurial". An institution with a much longer history, Stanford University, "remains dedicated […] to preparing our students to become the next generation of leaders"[5]. Leadership, critical thinking skills and perspective taking based on real-life professional experience are emphasised among the objectives of Pace University[6]. In Europe, the French EM Lyon Business School aims to educate "entrepreneurs for the world"[7]. Designing challenging teaching units that encourage skills such as independent thinking, experimentation and communication is the objective of Bielefeld University in Germany[8]. Aalto University in Finland seeks to train "broadminded experts with a comprehensive understanding of complex subjects to act as society's visionaries"[9]. In Japan, among the key missions of the Keio University graduate programmes is "to cultivate individuals with highly specialised skills who can serve as the next generation of leaders" and "make valuable contributions to tomorrow's society"[10].

This section briefly illustrates the recent trends in higher education teaching worldwide. After depicting some governmental and private as well as international initiatives for teaching effectiveness, the focus is put on new models of teaching and learning as increasingly adapted by higher education institutions.

Promotion of excellence in higher education teaching and learning

Corresponding to the increasing focus on skills for innovation, various measures to promote and assess excellence and innovation in teaching of higher education institutions have taken place around the world. These schemes range from governmental innovation funds to private and international initiatives to assess and empower higher education teaching and learning. Ability of and expectation for the higher

education sector to produce an adequately skilled workforce becomes increasingly important in the globalised knowledge economy (OECD, 2009).

Many governments have established specific schemes to support higher education institutions to innovate and improve teaching and student learning. In Japan, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) uses project-based incentive funds to encourage experimentation of innovative teaching and learning in higher education (Yonezawa and Kim, 2008). Since 2003, for example, the Support Programme for Distinctive University Education has sought to improve future higher education by selecting distinctive and outstanding education projects for support. Annually changing priorities for improvement projects may cover themes such as curriculum, teaching methods, student support or local co-operation[11]. In Australia, a national focus was put on higher education teaching and learning with the establishment of the Australian Learning and Teaching Council (ALTC) in 2004[12]. The ALTC seeks to improve student learning in higher education by supporting quality teaching and practice through award, fellowship and grant schemes such as the Innovation in Learning and Teaching grant. In Germany, the nation-wide Excellence in Teaching competition is a recently introduced grant scheme that recognises and supports innovative teaching in higher education[13]. The competition is organised jointly by the Standing Conference of the Ministers of Education and Cultural Affairs of the German *Länder* and the *Stifterverband* for German Science and Research, an innovation agency of the business community. In France, the 2008 higher education reform included a plan to foster innovation in teaching at the undergraduate level.

The higher education community in several countries, together with private foundations and enterprises, has also launched several initiatives focused on improving teaching and learning. In the United States, the Council for Aid to Education launched the Collegiate Learning Assessment (CLA)[14] in 2000. By directly measuring student learning outcomes, the CLA aims to provide a continuous improvement model for higher education teaching and learning with focus on skills such as critical thinking and problem-solving. CLA Education, launched in 2009, provides programmes to empower faculty in this respect. As a disciplinary initiative, the American Sociological Association launched Teaching Resources and Innovations Library for Sociology (TRAILS) in 2010 in the form of an electronic database to create and disseminate peer-reviewed teaching resources[15]. In the United Kingdom, the Higher Education Academy aims at supporting "the best possible learning experience for all students"[16]. Its many activities include providing bid-based grants for innovations in teaching and learning, supporting evidence-based research and disseminating the best practices in student learning. In Germany, Stiftung Mercator and the Volkswagen Foundations launched a nation-wide Bologna – The Future of Teaching grant-initiative in 2009 to support future university teaching through curriculum development and pooling of teaching expertise[17]. In addition, the charitable arm of the multinational Hewlett Packard (HP) has supported innovation in higher education teaching and learning through its HP Catalyst Initiative focusing on science, technology, engineering and mathematics education and the 21st century skills, for example[18].

The ability of higher education institutions to provide their students with the variety of skills needed in the future is receiving international attention too. At the European level, the European Institute of Innovation and Technology (EIT) was set up in 2008 to stimulate leading innovations for sustainable growth and competitiveness in the continent[19]. In addition to creating new innovations and innovation models, the EIT seeks to *"train a new generation of entrepreneurs, who have the right skills and knowledge to turn ideas into new business opportunities"*. As its operational base, it relies on Knowledge and Innovation Communities (KICs) that are clusters integrating higher education, research and business actors into creative partnerships. Higher education institutions within the KICs are envisaged, among other things, to take a leading role in developing innovative curricula and teaching that promote scientific, entrepreneurial and creativity skills. More generally, the Council of the European Union (2011, p. 7) supports "the adoption of student-centred approaches to teaching and learning, acknowledging the needs of a diverse student body and promoting a greater variety of study modes" (see also European Council and

Commission, 2010; European Students' Union, 2010; European University Association, 2010). With a clear focus on higher education teaching and learning, the OECD's feasibility study on an international Assessment of Higher Education Learning Outcomes (AHELO) was launched in 2008. The initiative aims to internationally evaluate higher education students' discipline-specific skills in engineering and economics as well as more generic, transferable skills such as critical thinking and problem solving – following the CLA model. Eventually, AHELO could help higher education institutions to improve their teaching and governance to direct their resources better, while increasing information for students and employers (OECD, 2010-2011).

Experimentations with new models of teaching and learning

Several higher education institutions around the world are experimenting with innovative approaches to teaching and learning in order to train future generations with skills for innovation. For example, Harvard University launched a new Initiative for Learning and Teaching (HILT) in 2012 "to encourage pedagogical innovation and strengthen learning and teaching throughout the University". Supported with a USD 40 million grant, the initiative encompasses activities from underwriting faculty- and student-initiated innovations, to reorganising classrooms and building expertise in evaluating teaching effectiveness[20]. In general, interdisciplinary and multi-disciplinary approaches appear increasingly popular in higher education curricula, together with entrepreneurial, intercultural and working world experience. In teaching, the focus is put on students' learning processes – especially with the increasing use of PBL. Overall, teaching matters in higher education institutions who seek to be recognised as high quality education providers. While current rankings of higher education institutions focus largely on research, students also demand education with labour market value that provides them with skills relevant for today and tomorrow (Hénard, 2010). This competition for students will take place in an increasingly globalised context (OECD, 2009). At the same time, research on how people learn has laid the groundwork for new insights into learning leading to new approaches to the design of curriculum, teaching and assessment.

Interdisciplinary curricula and multi-disciplinary education are at the heart of the strategies by which many higher education institutions seek to train future innovators and leaders. For example, in the United States, Mercer University established its School of Medicine in 1982 with undergraduate medical education operating with complete basic science integration (Doner and Bickley, 1993). Harvard University has integrated biological, social, behavioral and clinical sciences under its New Pathway Medical Programme since 2006[21]. The "Biodesign" programme of Stanford University has brought together students from engineering, management, genetics, biology, medicine and business since 2003 to train medical technology innovators (Stanford Report, 2009). The Franklin W. Olin College relies on an interdisciplinary approach in its curriculum that focuses on entrepreneurship and liberal arts, in addition to rigorous science and engineering fundamentals. The aim is to provide creative and inventive engineering education with skills to design and meet customer needs and business realities – such as team-work, financing, and marketing skills. Combining science, business and design, Aalto University was created in 2010 as a merger between the Helsinki School of Economics, the Helsinki University of Technology and the University of Art and Design Helsinki. The new university offers multi-disciplinary programmes such as the Creative Sustainability programme that focuses on scientific knowledge relevant to sustainable design and business with the aim to enhance students' strategic and comprehensive (re-)thinking. In the Netherlands, the Radboud University, Nijmegen, offers trans-disciplinary science courses such as general natural sciences or environmental sciences to attract students with broad science interests (OECD, 2008). An interdisciplinary approach is promoted by locating almost all university departments in one building in Bielefeld University – a winner of the Excellence in Teaching competition. In Japan, the separate Shonan Fujisawa Campus of Keio University offers interdisciplinary programmes in policy management, environmental information, nursing, and medical care. The graduates of the programme have been well received by Japanese multinational enterprises, traditionally preferring pure social science graduates (World Bank, 2002).

Several higher education institutions also put an explicit focus on entrepreneurship and working world experience, together with intercultural exposure, in their curricula. The French EM Lyon Business School emphasises entrepreneurship and business world connections in all its programmes, while it offers also specific programmes for entrepreneurs. For example, in-company internships and teaching by industry experts form an integral part of the MSc in Management programme seeking to prepare students with skills for their whole career. The programme includes a mandatory study period of at least six months in a country other than the students' home country – a pattern that is increasingly common in higher education (OECD, 2009). Entrepreneurship is also a key area of focus in the curriculum of the Franklin W. Olin College, which offers academic partnerships with industry. In addition, students are envisaged to conduct some engineering activities in a culture other than their own. In Japan, Keio University's educational approach includes, among other things, support for venture business development, on-line cooperation with Asian countries and local-community co-operation.

PBL, in particular, has gradually become an increasingly popular student-centred approach in higher education teaching and learning across disciplines. It was developed in the late 1960s in medical education to facilitate learning basic science concepts in the context of clinical cases (Box 2). PBL has since been the most influential innovation in medical education. It is today used in most medical schools in the United States and in many other countries around the world (Wood, 2008). Moreover, PBL has been successfully adapted across various disciplines in higher education, including natural sciences, social sciences, or humanities. Schools of architecture, business, law, engineering, forestry, police science, social work, education and many other professional fields have picked up PBL (Ball and Pelco, 2006; Camp, 1996). Entire institutions have been designing PBL curricula, and new PBL programmes and courses have been adopted and further developed by institutions and educators around the world – shifting the curriculum from a faculty-centred approach to a more student-centred, interdisciplinary process (Barrett and Moore, 2011; Barrows and Tamblyn, 1980). PBL as an instructional practice continues to have a large impact across subjects and disciplines worldwide (Norman, 2005).

Indeed, PBL has become a popular approach for higher education institutions as they seek to train future innovators and leaders. In the United States, Stanford University is involved with PBL in several departments in varying degrees. For example, at the PBL Laboratory, Department of Civil and Environmental Engineering, multidisciplinary, geographically distributed teams each project team member has a unique area of expertise. Stanford University has also launched a specific, non-degree teaching centre, the d.school, to unblock students' imagination, creativity and innovation (Box 3). The Franklin W. Olin College curriculum emphasises project-based approach, open-ended problem-solving and teamwork. Students are expected to learn through open-ended projects every year. This includes, for example, a year-long team project conducted for a client towards the end of the studies and a project combining two subjects during the first year. Teamwork is meant to include both team member and team leader roles, while convincingly communicating their work to an expert audience is also part of the students' college experience. Since it was established in 1998, the Center for Teaching, Learning and Scholarship (CTLS) at the University of Samford has incorporated PBL into various undergraduate programmes within the Schools of Arts and Sciences, Business, Education, Nursing and Pharmacy[22]. In Japan, the Shonan Fujisawa Campus of Keio University has implemented problem-finding/problem-solving education since its founding in 1990. This approach has been gradually expanded to cover increasingly demanding disciplines and situations – from language and information literacy education to medical situations. Keio University's teaching projects have been recognised by MEXT support programmes for several consecutive years.

Box 2. Origins of problem-based learning in higher education

In higher education, problem-based learning (PBL) was pioneered by Howard Barrows and his colleagues at McMaster University, Faculty of Health Sciences in Canada in the late 1960s. At that time, a new medical school with an innovative educational approach for a three-year curriculum was established. Today, the PBL approach of McMaster University still follows the same basic steps (Walsh, 2005): (1) Identify the problem, (2) Explore pre-existing knowledge, (3) Generate hypotheses and possible mechanisms, (4) Identify learning issues, (5) Self study, (6) Re-evaluate and apply new knowledge to the problem, and (7) Assess and reflect on learning.

The dissatisfaction with medical education at the time was the motivation for establishing the new curriculum. It was recognised that traditional education failed to equip students with the skills they needed to keep up with new developments in medicine and Barrows and his colleagues were questioning whether preclinical science courses and traditional lectures would prepare physicians adequately for the practice of medicine. This practice was seen as requiring knowledge integration, decision-making, working together with others, and communicating with patients (Barrows, 1983; Barrows and Tamblyn, 1980). Yet, medical students lacked clinical reasoning, problem-solving, and critical thinking skills. There was concern that medical schools put a too heavy emphasis on memorisation of – potentially irrelevant or soon-to-be-outdated – facts instead of skills necessary to practice medicine (Barrows, 1983; Savery, 2006). At the same time, medical students themselves seemed to be disenchanted and bored with their education because they had to absorb vast amounts of information of which much was perceived to have little relevance to medical practice (Spaulding, 1969, cited in Barrows, 1996). Addressing many of the concerns of traditional instruction, PBL was designed to foster problem solving, critical thinking, collaboration and self-study skills as well as to increase the retention of facts and their recall in clinical situations (Barrows, 1983).

Over the past decades, PBL has been adopted by a growing number of medical schools in the United States and throughout the world to train health professionals. The medical schools at the University of Limburg at Maastricht in the Netherlands, the University of Newcastle in Australia, and the University of New Mexico in the United States were among the first that adapted the McMaster model of problem-based learning in the 1970s and 1980s. Later, medical schools at Harvard University or at the University of Hawaii, for example, also started to establish alternative tracks or to convert their entire curriculum. Subsequently, countless medical schools have developed problem-based curricula in courses, alternative curricula, or as an entire curriculum revision (Barrows, 1996; Camp, 1996).

PBL has also become a popular teaching approach in several European higher education institutions. In the Netherlands, PBL has been at the core of Maastricht University's orientation ever since it was founded in 1976[23]. Maastricht University applies PBL in all of its programmes with the aim to generate students that are independent, entrepreneurial problem-solvers. The university employs various versions of PBL as an educational model simulating a research-oriented working environment that gives students skills that they will take with them into their careers. For example, the Maastricht Faculty of Health, Medicine and Life Sciences was one of the first universities in Europe to implement PBL as the dominant educational strategy in medical education. The School of Business and Economics at Maastricht University has been using PBL in all of its degree programmes for over 20 years. The school stresses both theory and practice, and places a strong emphasis on the development of problem-solving skills, group-work skills, and self-directed learning skills. Also in the Dutch Radboud University Nijmegen, teaching is increasingly delivered in project-based and contextual manner to enhance skills such as communication and co-operation (OECD, 2008). In France, the students of the MSc in Management programme in EM Lyon Business School are required to create a virtual business project as part of their studies. This means managing the whole entrepreneurial process of company creation by working as a member of a team and receiving feedback from the business world.

Box 3. The d.school at Stanford University: "Can imagination be taught?"

Hasso Plattner Institute of Design – better known as the "d.school" – at Stanford University was established in 2000 as a teaching centre with the mission to "foment personal transformation". While the d.school does not offer degrees, its aim is to equip students with "a mindset and a problem-solving approach that augments the knowledge and skills they acquire in their degree programs at Stanford". Teachers with multidisciplinary backgrounds are meant to "immerse [students] in a system of innovative thinking, with specific goals for solving practical problems". The courses may build on input from any part of Stanford University, including themes such as "fostering democracy; aiding individuals with threatening medical profiles; or paving the way for the next great start-ups".

The d.school approach gathers students across disciplines to collaborative project teams to, first, reinvent themselves and, then, "maybe the world". Instead of only trying to solve ready-defined problems, students are meant to creatively identify "what needs fixing and how to go about it" with the help of direct observation and interviews. After identifying a problem worth of working on, students imagine possibilities through "ideation" and then select a solution for prototyping and testing. The whole cycle maybe re-done several times with physical or virtual products, services or activities as outcomes. According to d.school founder David Kelley, "it all falls under the rubric of 'design thinking' [...] I think everybody's creative [...] I just always felt like they had blocks, that they weren't being allowed to be creative. So it became more and more clear to me that this was something that was pent up inside of people".

The d.school approach has received great interest within and outside Stanford University. Stanford University graduate students with diverse backgrounds compete for the access to the d.school courses. "[D]eploying the d.school's teaching model across the University" is not without interest either. Other parties approach the d.school weekly about possibilities to create similar educational programmes and the staff "has helped construct curricula, demonstrate classes or offer workshops in more than 30 countries".

Source: Antonucci (2011).

NOTES

[1] See the OECD Innovation Strategy www.oecd.org/innovation/strategy.

[2] See the OECD Skills Strategy www.oecd.org/education/SkillsStrategy.

[3] See the New Commission on the Skills of the American Workforce http://www.skillscommission.org/.

[4] See Franklin W. Olin College www.olin.edu/.

[5] See Stanford University www.stanford.edu/.

[6] See Pace University www.pace.edu/.

[7] See EM Lyon Business www.em-lyon.com/english/corporate/index.aspx.

[8] See Bielefeld University www.uni-bielefeld.de/International/.

[9] See Aalto University www.aalto.fi/en/.

[10] See Keio University www.keio.ac.jp/ and www.sfc.keio.ac.jp/en/top.html.

[11] For information in English, see for example Japan University Accreditation Agency http://www.juaa.or.jp/en/index.html.

[12] See the Australian Learning and Teaching Council www.altc.edu.au/.

[13] For information in English, see for example Bielefeld University www.uni-bielefeld.de/International/, RWTH Aachen University www.rwth-aachen.de/go/id/bdz/ and University of Freiburg www.uni-freiburg.de/.

[14] See the Council for Aid to Education www.cae.org/ and the Collegiate Learning Assessment www.collegiatelearningassessment.org/.

[15] See Teaching Resources and Innovations Library for Sociology http://trails.asanet.org/Pages/default.aspx.

[16] See the Higher Education Academy www.heacademy.ac.uk/.

[17] See Mercator Foundation on Bologna – The Future of Teaching www.stiftung-mercator.de/en/centres/science-and-humanities/bologna-the-future-of-teaching.html.

[18] See the HP Catalyst initiative http://www8.hp.com/us/en/hp-information/social-innovation/catalyst.html.

[19] See the European Institute of Innovation and Technology http://eit.europa.eu/.

[20] See Harvard Initiative for Learning & Teaching (HILT) http://hilt.harvard.edu/.

[21] See the New Pathway Medical Program, Harvard University http://hms.harvard.edu/ec_vqp.asp?Name_GUID=%7B7D63742B-05F7-4F58-8441-46C8C0BF6A2A%7D.

[22] See Center for Teaching, Learning and Scholarship (CTLS), Samford University http://www.samford.edu/ctls/archives.aspx?id=2147484112/.

[23] See Maastricht University http://www.maastrichtuniversity.nl.

PROBLEM-BASED LEARNING TO DEVELOP SKILLS FOR INNOVATION

PBL surfaced over 40 years ago as a reaction to the problems and shortcomings of conventional educational approaches (Barrows, 2002) – such as direct instruction. For example Schwartz, Lindgren and Lewis (2009, p. 57) argue that direct instruction "tends to focus students' attention to the told-solution procedures, not problem situations, so students learn answers to a problem space they never come to understand". With conventional approaches, students risk noticing only the eye-catching surface features of a problem and fail to recognise the structure beneath. As a result, they might not be prepared to transfer their knowledge and skills to new situations (Schwartz, Lindgren and Lewis, 2009). Effective, outcome-based higher education cannot rely exclusively on memorisation through drill and practice, or high-stakes standardised testing. Instead, education has to create learning environments that allow students to make sense of what they learn and process content deeply so that they can apply their understanding to solve problems (Bransford, Brown and Cocking, 2000).

In this context, PBL offers an attractive alternative to traditional approaches by shifting the emphasis from what is taught to what the student learns. PBL is designed to develop transferable skills along with the appropriate discipline-specific knowledge, while knowledge is learned in the same context in which it is used later on (Barrows, 1985; Bransford, Brown and Cocking, 2000). Student-centred and inquiry-based PBL approaches draw upon adult learning theory as well as cognitive and social constructivism. Learning is seen as an active, self-directed process with students working together in groups to solve complex real-world problems. This facilitates the acquisition of discipline-specific knowledge and attitudes as well as generic skills, which students can use in their personal life and careers. Students develop an integrated body of knowledge from many different subject areas or disciplines as well as transferable skills such as problem-solving, critical and creative thinking, communication and leadership skills (Barrows and Tamblyn, 1980). PBL is seen as allowing students to activate whatever prior knowledge is available to them, contribute it to the problem discussion and share their experiences in a small group. Activating their formal or informal knowledge related to the authentic problems or questions at hand facilitates the processing of new knowledge and, thus, understanding, since students can connect their prior knowledge in long-term memory. Group discussions further allow for elaboration and understanding as students explain their ideas to others and negotiate the meaning of those ideas. PBL can encompass more or fewer scaffolding structures – such as tutors, media for self-study or collaborations skills training – in response to the needs expressed by students (Hmelo-Silver, Duncan and Chinn, 2007).

This part of the report explores whether PBL can be more effective than traditional higher education teaching in developing a variety of skills for innovation. After presenting the central characteristics of PBL, the focus is put on examining the empirical evidence on the effectiveness of PBL in developing skills for innovation. Finally, some challenges for PBL research will be discussed.

Definitions of problem-based learning

PBL requires students to work together in small groups to solve real-world problems. The demands of the problem are the drivers for student self-direction and PBL is often configured as a specific type of project focusing on problem definition and solution strategies [1] (Barron and Darling-Hammond, 2008).

Box 4. Four key components of PBL

Barrows has identified four key components of PBL:

- Ill-structured problems are presented as unresolved so that students will generate not just multiple thoughts about the case of the problem, but multiple thoughts on how to solve it. Such problems may not have a single correct answer and should engage students in the exploration of multiple solution paths.
- A student-centred approach consists of students determining what they need to learn. It is up to the learners to derive the key issues of the problems they face, define their knowledge gaps, and pursue and acquire the missing knowledge.
- Teachers act as facilitators or tutors in the learning process. These tutors, typically faculty, initially prompt students with meta-cognitive questions and in subsequent sessions fade that guidance. Tutors forgo lecturing about content in favour of modelling the kinds of learning processes that lead to success in PBL settings.
- Authenticity forms the basis of problem selection, embodied by alignment to professional or "real world" practice. As such, the problems are inherently cross disciplinary and require students to investigate multiple subjects in order to generate a workable solution.

Source: Adapted from Barrows (2002), and Walker and Leary (2009, pp. 13-14).

The concept of PBL has evolved over time, emphasising student engagement, interaction as well as tailored scaffolding to support students' understanding. In a classical definition stemming from medical education, problem-based learning "is the learning that results from the process of working towards the understanding of a resolution of a problem [...] encountered first in the learning process" (Barrows and Tamblyn, 1980, p. 1). In a more recent definition, Barrows (2002) identifies four key components of PBL: ill-structured problems, student-centred approach, teacher as facilitator, and authenticity (Box 4). Savery (2006, p. 12) understands PBL as "an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem." Schmidt, Loyens, van Gog and Paas (2007) argue that PBL is an instructional approach with elements that allow for flexible adaptation of guidance compatible with humans' cognitive architecture. Specifically, it is characterised by the use of problems that actualise important scientific ideas as the starting point, small-group collaboration of 6-10 students, flexible guidance, a limited number of lectures, student-initiated learning and ample time for self-study (Schmidt, Van der Molen, Te Winkel and Wijnen, 2009). Consequently, successful constructivist curricula have four conditions:

> "First, problems or assignments used as the starting point of small-group discussion and self-directed learning should be promoting epistemic curiosity and should be perceived by students as relevant to their personal strivings. Second, small group work should enable the activation of prior knowledge and elaboration on what is learned. Third, tutors should engage themselves actively in didactic conversations with the learners and provide appropriate scaffolds. Fourth, students need ample time for self-directed learning using resources that (to some extent) represent their own interests and preferences." (Schmidt, Van der Molen, Te Winkel and Wijnen, 2009, p. 240).

In particular, providing students with adequate guidance and structure towards focused educational goals should form an integral part of effective PBL. This could mean presenting students with problems of high quality, facilitating small-group collaboration or otherwise scaffolding the process to foster self-

directed learning. Earlier research comparing guided and unguided instruction/pure discovery learning in different educational contexts from elementary to higher education tends to produce empirical results in favour of guided instruction. For example, based on his literature review, Mayer (2004, p. 18) concludes that the "debate about discovery has been replayed many times in education but each time, the evidence has favoured a guided approach to learning". He submits that guided discovery – i.e. knowing how much and what kind of guidance to provide and how to specify the desired learning outcome – appears to be the "best method" to facilitate learning[2]. Also McCray, DeHaan and Schunk (2003) suggest in their review that more strongly guided instruction is more effective than unguided approaches in undergraduate engineering, technology, science, and mathematics education. Kirschner, Sweller and Clark (2006) cite controlled experimental studies supporting instructional guidance, especially in science learning (e.g. Brown and Campione, 1994; Moreno, 2004). Moreover, differences between novices and experts indicate that in order for students to acquire a rich body of flexible, easily retrieved information as well as expert reasoning skills, guidance by instructions in continual application of acquired knowledge to real world problems is necessary (Barrows, 1985; Bransford, Brown and Cocking, 2000).

For PBL to be effective, guidance and scaffolding structures need to be flexibly adapted to the learners' level of expertise and to the complexity of the learning task. The scaffolding structures can be tailored to optimise the relationship between the intrinsic cognitive load imposed by the task and the extrinsic cognitive load imposed by the instruction (Schmidt, Loyens, van Gog and Paas, 2007). The intrinsic cognitive load means the extent to which the information that is to be learned can or cannot be understood in isolation, whereas the extrinsic cognitive load refers to the type of assignment or learning activity. Thus, PBL is not necessarily a minimally guided instruction model because it can incorporate many forms of scaffolding – including forms of direct instruction (Hmelo-Silver, Duncan and Chinn, 2007). For example, Schmidt, Van der Molen, Te Winkel and Wijnen (2009, p. 238) categorise the teacher's repertoire of activities to support student learning as follows:

- Forms of direct instruction that occur in response to the needs expressed by student. This can include transmitting subject matter, explaining or directing students towards important learning goals.

- Forms of instructional scaffolding such as engaging in purposeful conversations with students, encouraging and rewarding students and providing feedback upon learning.

As a case in point, the "Seven Jump Step" approach applied in the University of Maastricht is a model for scaffolding PBL (Box 5). Students work together in groups of 5 to 12 members with one person appointed as a Chair and another as a Minutes Secretary. The Chair and Minutes Secretary can be rotated at each session. The instructor hands out the problem to the Chair, who distributes it to the rest of the group. The role of the Chair is to guide the discussions of the group but all students should be involved in them. The role of the instructor is to facilitate the learning process by helping the Chair to maintain group dynamics and moving the group through the tasks. The instructor also ensures that the group achieves adequate learning objectives in line with the curriculum.

Box 5. 'Seven Jump Step' approach to PBL in the University of Maastricht

- *Step 1.* Identify and clarify unfamiliar terms presented in the scenario; scribe lists those terms that remain unexplained after discussion
- *Step 2.* Define the problem or problems to be discussed; students may have different views on the issues, but all should be considered; scribe records a list of agreed problems
- *Step 3.* "Brainstorming" session to discuss the problem(s), suggesting possible explanations on basis of prior knowledge; students draw on each other's knowledge and identify areas of incomplete knowledge; scribe records all discussion
- *Step 4.* Review steps 2 and 3 and arrange explanations into tentative solutions; scribe organises the explanations and restructures, if necessary
- *Step 5.* Formulate learning objectives; group reaches consensus on the learning objectives; tutor ensures learning objectives are focused, achievable, comprehensive, and appropriate
- *Step 6.* Private study (all students gather information related to each learning objective)
- *Step 7.* Group shares results of private study (students identify their learning resources and share their results); tutor checks learning and may assess the group

Source: Adapted from Wilkerson and Gijselaers (1996), and Wood (2003).

Effectiveness of problem-based learning

While the components of PBL are well known, the key question is its impact on students' acquisition of different kinds of skills for innovation. In this section we explore whether there is empirical evidence that PBL is an effective instructional approach, especially in comparison with more traditional teaching methods – such as lecturing supplemented by exercises and classroom discussions on assigned readings with the instructor as the "sage on the stage" disseminating information (e.g. Armstrong and Fukami, 2009).

For this report, we draw on large-scale reviews, meta-analyses, and meta-syntheses of the available PBL literature. Papers were identified through database and Internet searches of keywords and phrases related to problem-based learning or curricula, meta-analysis or meta-synthesis. The databases ERIC, Web of Science, JSTOR, PsycInfo and Education Abstracts were used to identify relevant peer-reviewed papers since 1993. Additional literature was identified from the Internet, library searches and reference lists. The selected sources were chosen for analysis based on the following criteria:

- Studies were published in English and research was mostly conducted in North America, Europe or Australia.
- Research addressed quantitative-oriented research conducted in colleges or universities (selected studies conducted in schools were included).
- Research addressed the topic of effectiveness/effects of PBL.

As a next step, the selected research papers were reviewed for close relevance and methodological rigor. Attention was paid to empirical research methods, measures of teacher effectiveness or classroom

practice, student outcomes and accepted standards for quality research (see Annex 1 for a list of the selected studies).

Overall, PBL has been one of the most researched pedagogical innovations in education. The vast majority of research on its effectiveness has been conducted in the field of medicine. For example, the database PubMed alone presents over 5 000 articles that use the term problem-based learning in their titles or abstracts (Schmidt, Rotgans and Yew, 2011). Most empirical studies describe and evaluate PBL innovations comparing them with conventional medical education based on knowledge tests and involve large samples of students or graduates (Schmidt, van der Molen, te Winkel and Wijnen, 2009). Hence, this report covers studies conducted primarily in medical education that have been reviewed extensively over the past 30 years (e.g. Albanese and Mitchell, 1993; Colliver, 2000; Dochy, Segers, Van den Bossche and Gijbels, 2003; Gijbels, Dochy, van den Bossche and Segers, 2005; Vernon and Blake, 1993). These earlier results are blended with more recent meta-analyses and meta-syntheses that also expand the disciplines covered. The majority of data with regard to the outcomes of PBL are descriptive and quasi-experimental (Mennin, Gordan, Majoor and Al Shazali Osman, 2003).

For the purpose of this analysis, results were categorised into three pragmatic categories based on student learning outcomes:

- Knowledge acquisition and academic achievement;
- Reasoning and knowledge application;
- Social and behavioural skills.

Overall, PBL appears to fare very well against more traditional teaching – regarding a variety of objectives and disciplines – with newer studies favouring PBL more than older studies.

Knowledge acquisition and academic achievement

PBL appears to be more or less in a same standing with more traditional programmes when looking into students' test performance in medical education. The performance on tests of basic science of medical students participating in PBL is not statistically different from the performance of students in more traditional medical education. This refers to acquiring medical knowledge that can be recalled in a standardised testing format such as the United States Medical Licensing Examination (USMLE) Step 1 exam. The difference in performance was not found to be statistically significant by Vernon and Blake (1993) who analysed five meta-analyses covering 35 studies from 19 institutions mostly located in the United States dating from 1970 through 1992 (see also Mennin et al., 2003). A narrative meta-analysis by Berkson (1993) on medical education included PBL literature through 1992 and concluded that "the graduate of PBL is not distinguishable from his or her traditional counterpart". Colliver (2000) conducted a review of the medical education literature published from 1992-1998 in nine medical education and medicine journals, including three meta-analyses (Albanese and Mitchell, 1993; Berkson, 1993; Vernon and Blake, 1993). He analysed the effects of PBL on educational outcomes as well as the magnitude of these effects. Colliver concluded that there is no significant evidence for the superiority of PBL regarding performance on standardised tests or instructor-designed tests during the first two years of medical school. Smits, Verbeek and de Buisonjé (2002) reached similar conclusions when researching the effects of PBL in continuing medical education on the basis of controlled evaluation studies conducted from 1974 to 2000. Dochy, Segers, Van den Bossche and Gijbels (2003) conducted a quantitative meta-analysis including 43 quasi-experimental field studies of PBL in higher education mainly conducted in the United States. They report that no robust effect of PBL was found on declarative knowledge tests, at least for the time of conducting the study, and the statistically non-significant advantage (5 % level) of conventional instruction

disappeared after the second year of medical education. In comparison, Bligh (2000) found that lecturing was equal or superior to methods such as discussions or exercises in class when the objective was learning facts and general information.

The benefits of PBL over traditional approaches seem to become more visible when examining higher education students' long-term retention of knowledge. While PBL students may be slightly inferior to traditional students in overall knowledge and competence, they appear to be superior in long-term recall and retention (Norman and Schmidt, 2000; Schmidt and Moust, 2000). Along these lines, Albanese and Mitchell's (1993) meta-analysis-type review of English-language international literature involving studies mainly conducted in the United States found that PBL graduates perform as well and sometimes better on clinical examinations and are evaluated as good if not better by their faculty supervisors in terms of analysing patient problems and achieve diagnoses than their traditional counterparts. PBL students show patterns of higher resource utilisation per patient and have more study hours each day. In a few instances PBL students scored lower on basic sciences examinations and viewed themselves as less well prepared in the basic sciences. The review compared PBL to traditional medical education instruction covering 20 years (1972-1992) of research relying on a narrative integration (Albanese and Mitchell, 1993). In contrast, when looking into large lecture courses in higher education in the United States, for example, Twigg (2000) points out that students who pass are often not able to retain what they have learned. Also the drop-out rates, D grades, and failures in lecture courses can range from 15% up to 45% depending on institutional type and subject matter.

A more recent meta-analysis seconds that PBL appears to benefit especially students' understanding. Gijbels, Dochy, Van den Bossche and Segers (2005) conducted a meta-analysis including 40 empirical and quasi-experimental studies from 1976 to 2000 in medical education mostly in the United States, except for one in the field of economics. They used three outcome measures based on Sugrue's (1995) model of cognitive components of problem solving to determine the effects of PBL compared to conventional instruction: (1) understanding of concepts, (2) understanding of the principles that link concepts, and (3) linking of concepts and principles to conditions and procedures for application. The results indicate that PBL had the most positive effects when the constructs being assessed were at the level of understanding principles that link concepts (effect size 0.80 based on 15 studies, significant at the 5% level). At the first level, understanding concepts, PBL students performed at least as well as students exposed to conventional instruction (effect size 0.07) and the third level concerning application showed no negative effects and slightly positive effects (effect size 0.34). The last two effect sizes were not statistically significant, partly due to the fact that only 8 out of 40 studies focused on the third level.

More recent studies concur that PBL is more effective than traditional instructional approaches regarding several types of learning outcomes apart from short-term knowledge acquisition and retention. Strobel and Van Barneveld (2009) compared and contrasted the assumptions and findings of meta-analytical research on the effectiveness of PBL for the workplace. Their qualitative meta-synthesis approach drew on eight meta-analyses and systematic reviews of studies mainly conducted in the United States (1993-2005) in medicine and other disciplines such as economics and computer science. The data were grouped into the following four high-level categories based on the assessment of learning outcomes (Table 1):

- *Knowledge assessment.* This category focuses on short-term or long-term knowledge acquisition and retention. Short-term knowledge acquisition and retention include measures such as the United States Medical Licensing Examination (NBME 1), multiple choice questions, progress assessments using 250 True/False questions, or free recall where students are asked to write down everything they remember on a topic. Long-term knowledge acquisition and retention measures compare immediate post-course results and results on the same test after a period of between 12 weeks to two years, for example.

- *Performance or skill-based assessment*. This category includes observations with clinical ratings such as formative assessment by a supervisor during and at the end of performance. It includes also measures such as the United States Medical Licensing Examination (NBME 2) or case studies.

- *Mixed knowledge and skill-based assessment.* This category includes measures such as oral examinations and the United States Medical Licensing Examination (USMLE 3).

- *Non-performance, non-skill-oriented, non-knowledge-based assessment*. This category includes measures such as student and faculty satisfaction as well as successful assignment of first choice of residency.

The findings indicate that "PBL is significantly more effective than traditional instruction to train competent and skilled practitioners and to promote long-term retention of knowledge and skills acquired during the learning experience or training session" (Strobel and van Barneveld, 2009, p. 55). PBL was found to be effective in three of the four categories with the exception of knowledge assessment. The knowledge assessment category showed mixed results, tending to favour traditional learning approaches for short-term knowledge acquisition, but PBL was more effective for long-term knowledge retention. Dochy, Segers, Van den Bossche, and Gijbels (2003) submit that "the better an instrument was able to evaluate students' skills, the larger the ascertained effects of PBL" (cited in Strobel and van Barneveld, 2009, p. 51). Strobel and Van Barneveld (2009, p. 55) provide the following recommendation regarding the effectiveness of PBL:

> "PBL instruction was effective when it came to long-term retention and performance improvement. PBL students were overall slightly underperforming when it came to short-term retention. Ultimately, the goal of instruction should be performance improvement and long-term retention. Therefore, preference should be given to instructional strategies that focus on students' performance in authentic situations and their long-term knowledge retention, and not on their performance on tests aimed at short-term retention of knowledge."

Finally, the positive impact of PBL in comparison to more conventional programmes can become more visible when using different measures of study progress and success. Research suggests that time studying curricular materials (time on task) is a major contributor to learning (Schwartz, Lindgren and Lewis, 2009). In a four-year study of 8 643 students related to 60 university courses in four Dutch universities, Van den Berg and Hofman (2005) found that time devoted to study had a positive effect on study success. Offering few parallel study units was positively correlated with the study progress achieved. While the study focused on student and faculty factors that determine study progress and the numerical success rate in higher education, the authors also suggest introducing more problem-based instruction to intensify the educational process and thus influence the study progress. Moreover, fewer students dropped out (medium effect on graduation rate) and students also needed less time to graduate (e.g. Schmidt et al., 2009). In their qualitative meta-synthesis of studies mainly conducted in the United States, Strobel and Van Barneveld (2009) found that PBL students were also more often accepted to their first choice of residencies.

Table 1. Traditional approaches versus PBL (effect sizes)

	Basis of the assessment																
	Knowledge						Performance or skills						Mixed knowledge and skills		Non-performance, non-skill and non-knowledge		
	Short-term					Long-term retention	Case analysis					Observation ratings			Satisfaction		
									Case-based								
	NBME 1	Multiple-choice	Short Answers	Progress	Free recall		NBME 2	Patient simulations	Cases	Essay questions	Modified essay		Oral	USMLE 3	Students	Faculty	1st choice residency
Albanese and Mitchell (1993)	-					+	+					+			+	+	+
Vernon and Blake (1993)	-	-					+					+			+	+	
Berkson (1993)	-						+			+							+
Kalaian, Mullan and Kasim (1999)	-						+										
Colliver (2000)	-											+			+		
Dochy, Segers, Van den Bossche, and Gijbels (2003)	-	-	+	-	+	+	+	+	+	+	+	+	+	+			
Newman (2003)	-	-							+	+							
Gijbels, Dochy, Van den Bossche, and Segers (2005)	-	-	+	-	-/+	-/+	+	+	+	+	+	+	-/+	+			
Overall effect size	**-**	**-**	**+**	**-**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**
Favours	**Traditional learning**						**PBL**						**PBL**		**PBL**		

+ = Effect sizes in favour PBL; - = Effect sizes in favour traditional teaching and learning approach.

NBME 1 = United States Medical Licensing Examination that assesses understanding and application of science concepts important to the practice of medicine; NBME 2 = United States Medical Licensing Examination that assesses application of medical knowledge, skills, and understanding of clinical science through essay questions; USMLE 3 = United States Medical Licensing Examination that assesses application of medical knowledge and understanding of biomedical and clinical science essential for the unsupervised practice of medicine, with emphasis on patient management.

Source: Strobel and Van Barneveld (2009).

Overall, a large body of research suggests that PBL students retain knowledge much longer and are more effective in integrating and explaining concepts than students who are taught traditionally. Yet, traditional learning approaches seem to be equally or more effective regarding short-term knowledge acquisition and retention of basic knowledge, for example, in national licensing examinations.

Reasoning and knowledge application

As to reasoning and application of knowledge into new situations, PBL students seem to outperform their peers participating in traditional medical education programmes. Research results indicate a small but significantly positive effect of PBL on measures of medical student diagnostic ability. Patel, Groen and Norman (1993) compared students from two different medical schools in Canada – McGill and McMaster – with basic science taught in the context of a conventional curriculum versus PBL curriculum. Students were asked to provide diagnostic explanations of a clinical case. The authors found that PBL students applied a backward- or hypothesis-driven reasoning strategy using a hypothesis to explain the data

as opposed to a forward- or data-driven reasoning strategy reasoning from the data to a hypothesis. Experts tend to go back to basic principles and effectively use hypothesis-driven reasoning rather than data-driven reasoning when faced with complex or unfamiliar problems. PBL students, who engaged in far more hypothesis-driven reasoning, created more elaborated and coherent explanations based on detailed biomedical information compared to the sparse explanations of students in the traditional curriculum. It is suggested that a backward reasoning strategy should lead to more flexible knowledge and problem-solving (e.g. Albanese and Mitchell, 1993; Hmelo et al., 1997; Schmidt, Van der Molen, Te Winkel and Wijnen (2009); see also Box 6).

Nevertheless, it is less clear that PBL students outperform students of traditional programmes in terms of applying knowledge accurately to familiar situations. Forward- or data-driven reasoning can be seen as essential when presented with familiar problems as it "relies on having a well-defined cognitive structure or schema from which a diagnosis can be achieved almost simultaneously with recognition of symptoms" (Walker and Leary, 2009, p. 15). Patel, Groen and Norman (1993) concluded that PBL impedes the development of expert data-driven/forward-directed reasoning strategies that are at the core of expertise in terms of familiar problems. In applying hypothesis-driven reasoning PBL students needed more time, were more likely to make errors, to generate less coherent explanations, and to use flawed patterns of explanation than their peers in traditional programmes. In contrast, in a later longitudinal quasi-experimental study with first year medical students in from two US medical schools, Hmelo (1998) found that PBL students generated more coherent and accurate problem solutions compared to traditional medical students despite their hypothesis-driven reasoning (see also Patel, Groen and Norman, 1993).

Overall, PBL helps medical students remember knowledge and apply it in clinical practice. For example, in a quantitative meta-analysis including 43 quasi-experimental field studies mainly conducted in the United States, Dochy, Segers, Van den Bossche and Gijbels (2003) report robust positive effects of PBL as compared to traditional instruction in terms of knowledge application. The findings in medical education revealed a moderate effect size of knowledge application (effect size 0.46). Several other meta-analyses also found that PBL students performed better on tests of clinical performance and skills compared to traditional medical students (e.g. Albanese and Mitchell, 1993; Gijbels, Dochy, van den Bossche and Segers, 2005; Vernon and Blake, 1993). Recent meta-analyses and syntheses including studies in diverse disciplines – although mainly from the field of medicine – found that performance or skill-based assessment clearly and consistently favours PBL with modest to high effect sizes (e.g. Schmidt et al., 2009; Strobel and van Barnefeld, 2009; Walker and Leary, 2009).

Moreover, PBL may be especially promising outside of medical education. For example, according to Ravitz (2009, p. 5) "[w]hile PBL generally 'broke even' in studies of science, engineering, and medicine, the most favourable results for PBL appeared in studies of teacher education, social science, business, allied health, and other disciplines". Walker and Leary's recent meta-analysis (2009)[3] examines the impact of PBL regarding 47 outcomes outside medical education and allied health (Table 2). In sum, the authors found that "PBL students either did as well as or better than their lecture-based counterparts, and they tended to do better when the subject matter was outside of medical education" (Walker and Leary, 2009, p. 24). Combining 82 different studies from 1976 to 2007 mainly conducted in the United States, the analysis spanned 201 outcomes with a small effect size in favour of PBL (0.13, +/- 0.025 and a statistically significant vote count analysis with 68 positive outcomes and only 21 negative in favour of PBL ($p<0.001$). The 133 outcomes from medical education resulted in a small effect size (0.09), while studies involving teacher education (four outcomes; effect size 0.64) or the social sciences (six outcomes; effect size 0.30) seem to be more promising. Science (12 outcomes; effect size 0.06) and engineering (five outcomes; effect size 0.05) seem to be the least favourable disciplines for PBL. The authors categorise studies according to problem types used, PBL approaches employed and assessment level applied to quantify the effects of PBL compared to traditional curricula.

Table 2. Discipline area outcomes

	Vote count analysis[4]			Effect sizes (weighted by sample, Cooper, 1989)		
	Positive significance	*Negative significance*	*Number of outcomes*	*Cohen's d for means*	*Lower confidence interval*	*Upper confidence interval*
Discipline						
Teacher education	1	0	4	0.64	0.44	0.83
Other	5	0	13	0.48	0.31	0.66
Social science	3	0	6	0.30	0.10	0.50
Allied health	5	0	22	0.26	0.18	0.34
Business	3	0	6	0.16	0.03	0.29
Medical education	45*	16	133	0.09	0.06	0.12
Science	4	4	12	0.06	-0.06	0.19
Engineering	2	1	5	0.05	-0.20	0.29
All	*68**	*21*	*201*	*0.13*	*0.10*	*0.15*
Assessment level						
Concept	19	15	73	-0.04	-0.09	0.01
Principle	12*	4	40	0.21	0.14	0.27
Application	28	0	60	0.33	0.29	0.38
Mixed (concept and application)	0	0	1	0.17	-0.36	0.69
Missing	9*	2	27	0.07	0.02	0.12
All	*68**	*21*	*201*	*0.13*	*0.10*	*0.15*
Problem type						
Story	0	0	1	0.11	-1.09	1.31
Troubleshooting	2	0	6	0.19	0.02	0.37
Diagnosis solution	52*	16	153	0.11	0.08	0.14
Strategic performance	0	0	2	0.53	0.21	0.85
Design	1	0	3	0.74	0.52	0.96
Dilemmas	3	3	8	0.18	-0.33	-0.03
Missing	10*	2	28	0.26	0.18	0.34
All	*68**	*21*	*201*	*0.13*	*0.10*	*0.15*
PBL method						
Closed-loop	3	0	5	0.54	0.42	0.66
Missing	65*	21	196	0.11	0.08	0.13
All	*68**	*21*	*201*	*0.13*	*0.10*	*0.15*

*Significant ($p<0.05$) sign test on the vote count analysis.

Source: Walker and Leary (2009)

With differences across disciplines, Walker and Leary (2009) found that findings favour PBL in comparison with more traditional instruction (Table 2):

- *Assessment level.* Concept-level outcomes (referring to declarative knowledge) are almost identical between PBL and lectures (73 outcomes; effect size -0.04). Regression analysis shows principle-level outcomes and application-level outcomes favoured PBL, albeit with modest effect sizes (0.21 and 0.33). The former refers to relationships between concepts based on some sort of an underlying probabilistic model and the latter to application conditions and procedures for

using principle and concept knowledge to achieve a goal state and/or in new situations. PBL students were also found to engage in more hypothesis-driven and less data-driven reasoning than their lecture-based counterparts in a separate analysis (effect size 0.49, +/-0.23).

- *Problem type.* Most of the literature includes diagnosis-driven problem types (153 outcomes, effect size 0.11) that involve weighing alternative options for solving a problem and monitoring progress. Design problems meaning complex and ill-structured problems incorporating knowledge that crosses disciplines produced one of the largest single effect sizes found in the review (three outcomes, effect size 0.74) suggesting a trend further along from classic medical education PBL such as diagnosis solution. This was the case also for strategic-performance problems that required thinking both strategically and tactically (two outcomes, effect size 0.53).

- *PBL method.* Most of the 68 studies did not provide information on the PBL method used, only three referred to using closed-loop approaches. The studies that used closed-loop problem-based learning indicated some of the largest findings in favour of PBL including assessments at the concept, principle and application level (effect size 0.54). In closed-loop problem-based approaches learners are asked to revisit the problem to determine any improvements they could make to their reasoning process (e.g. by evaluating the information resources used and their own prior knowledge).

Overall, research suggests that PBL has small but significantly positive effects on students' diagnostic abilities and clinical reasoning skills – especially when students engage with unfamiliar problems. PBL students seem to be overall better prepared to apply their learning to real-world situations, as performance or skill-based assessment clearly and consistently favours PBL with modest to high effect sizes. Meta-analyses (Ravitz, 2009; Walker and Leary, 2009) also indicate that PBL excels on other non-cognitive outcomes as compared to traditional instruction. Yet, in terms of applying knowledge accurately to familiar situations, studies show mixed results on whether PBL students are as or more effective than their lecture-based counterparts.

Social and behavioural skills

Students in PBL appear to employ more productive approaches to study, have better interpersonal skills and appear to be more motivated than students in more traditional higher education programmes.

PBL may boost medical students' self-confidence, learning skills and career preparedness. PBL can promote medical students' confidence in their problem-solving skills, it gives them a sense of ownership over their learning, and helps them to become life-long self-directed learners. This can put them at an advantage in future courses and in their careers as (medical) practitioners (Albanese and Mitchell, 1993; Colliver, 2000; MacKinnon, 1999). For example, medical graduates of McMaster University, Canada, and the University of New Mexico School of Medicine, the United States, report being as prepared or more prepared for post-graduate study and practice compared to graduates of traditional programmes. Clinical ratings by post-graduate supervisors found graduates from these PBL programmes to be equal or superior to other students in specified areas and competencies. For example, they were more likely to spend more time in direct patient care and to pay attention to psychosocial issues (Mennin et al., 2003). In their recent qualitative meta-synthesis, Strobel and Van Barneveld (2009) found that PBL students in various disciplines rate the quality of PBL instruction as higher than lecture-based instruction, for example, in terms of independent study and critical thinking (Schmidt et al., 2009). PBL students felt also better prepared in self-directed learning and problem solving skills. They have been found to use the library more often, and choose and utilise a wider variety of learning resources on their own (Mennin et al., 2003; Newman, 2003). In contrast, for example Bligh (2000) found that lecturing was not as effective for

promoting thought, changing attitudes and developing behavioural skills as other instructional methods such as discussions or exercises in class.

Recent studies have found PBL to benefit communication, interpersonal and teamwork skills too. For example, Nandi et al. (2000) found that medical students engaged in PBL seem to have superior interpersonal skills in effectively interacting with patients. They also showed better psychosocial knowledge and attitudes towards patients (see also Sanson-Fisher and Lynagh, 2005). These findings were based on a Medline literature research (1980 through 1999) summarising studies and meta-analyses researching PBL versus conventional lecture-based teaching in medical undergraduate education in the United States and elsewhere. Also Schmidt, Van der Molen, Te Winkel and Wijnen (2009) found that PBL students performed much better particularly in terms of communication skills and other work-supporting competencies such as the ability to work efficiently and in teams (Box 6). It is suggested that the small-group collaborations essential to PBL facilitate the acquisition of such skills.

The benefits of PBL on acquisition of social and behavioural skills were also found by other researchers. Systematic literature review by Koh, Khoo, Wong and Koh (2008) of 13 international articles published in 2006 suggests that PBL during medical school has particularly positive effects on physicians' social competence after graduation. The social competence includes teamwork skills, appreciation of legal and ethical aspects as well as of social and emotional aspects of health care and appropriate attitudes toward personal health and well-being. Moreover, moderate to strong evidence was found for coping with uncertainty (strong), communication skills such as communication with patients (moderate), and self-directed learning (moderate). Koh, Khoo, Wong and Koh's (2008) study selection criteria included PBL as a teaching method in medical education, physician competence assessed after graduation and a control group of graduates of traditional curricula. The study population ranged from first-year residents to physicians with up to 20 years of practice. The authors assessed the quality of the studies categorising competencies into eight thematic dimensions (overall, technical, social, cognitive, managerial, research, teaching and knowledge competencies) taking the level of evidence (self-reported and observed assessments) for each competency into account.

Box 6. Meta-analysis at the medical school of Maastricht University in the Netherlands

In a recent meta-analysis, Schmidt, Van der Molen, Te Winkel and Wijnen (2009) found that constructivist curricula with less direct instruction had positive effects compared to various conventional Dutch medical schools. Their analysis is based on computing effect sizes for most of the 270 comparisons in the context of a single well-established problem-based curriculum involving the medical school of Maastricht University in the Netherlands. The authors report on a broad range of outcome measures as compared to earlier studies focusing on the effects of knowledge acquisition alone (e.g. Shanley, 2007). Overall effect sizes were computed according to the size of the populations involved.

Overall, the PBL curriculum was found to have a more positive impact on student learning than more traditional programmes, particularly with regard to interpersonal skills like communication and teamwork, and student engagement:

- *Acquisition of medical knowledge* was examined through a "progress test" consisting of 200 to 300 questions that students routinely take four times a year covering medicine as a whole. Comparing student performance under PBL medical curriculum and in conventional medical schools, an overall weighted effect size averaged over 90 comparisons was equal to 0.07. This signified a small positive effect for PBL over conventional medical programmes. The effects found with regard to medical knowledge acquired were small with 3% in gains over the average student in a conventional curriculum.

- *Diagnostic reasoning* was researched by presenting to students a number of cases requiring them to produce a diagnosis. PBL had a small positive impact with effect size 0.11 over conventional programmes. Gains over the average student in a conventional curriculum were 5%.

- *Work-supporting competencies* such as communication and the ability to work efficiently and in teams showed the problem-based school to be superior with an overall weighted effect size equal to 0.69. Overall, PBL students and graduates performed much better in the area of interpersonal skills compared to those in conventional programmes with the former leaving behind about 92% of the latter.

- In the area of the more *domain-specific practical medical skills* such as blood pressure measurement or abdominal examination, the overall weighted effect size for the level of mastery of these skills was equal to 0.83. The average PBL student surpassed 79% of the students from conventional medical schools.

- *Student engagement* can be illustrated by looking at the graduation rates and the time needed to graduate (study duration). Of all students that entered Dutch medical education between 1989 and 1998, fewer students dropped out from PBL programmes than from conventional programmes and students received their degree faster as well. PBL had a medium positive effect on both graduation rate (effect size 0.33) and time needed to graduate (effect size -0.68) (Schmidt, Cohen-Schotanus and Arends, 2009). The average PBL student graduated quicker than 70% of students in the conventional medical school and the PBL school retained 12% more students as compared to the conventional schools.

In addition, students rated the quality of the PBL instruction as higher for example in terms of independent study and critical thinking.

Source: Summarised from Schmidt, Van der Molen, Te Winkel and Wijnen (2009).

Most studies suggest that PBL also has a positive impact on student satisfaction and motivation. Although a PBL curriculum may not always foster intrinsic motivation more than a traditional curriculum (Wijna, Loyens and Derous, 2011), much research on medical education suggests a positive PBL impact in this respect. Vernon and Blake (1993) found in their analysis of five meta-analyses covering 35 studies from 19 institutions mostly located in the United States dating from 1970 through 1992 that attitudes, class attendance and mood of PBL students were better as compared to students taught by traditional curricula (see also Albanese and Mitchell, 1993; Moore, Block, Style and Mitchell, 1994; Newman, 2003; Norman and Schmidt, 2000; Sanson-Fisher and Lynagh, 2005; Smits, Verbeek and de Buisonjé, 2002). PBL

students found their experience more nurturing, motivating and enjoyable (e.g. Albanese and Mitchell, 1993; Smits, Verbeek and de Buisonje, 2002; Vernon and Blake, 1993). Medical students in PBL tracks were more likely to report that their early medical school years were challenging, engaging, and satisfying as compared to students from traditional programmes, who report their experience as being rather irrelevant, passive, and boring (Mennin et al., 2003; Nandi et al., 2000). PBL seems to have a positive impact also on students' attitudes toward learning (e.g. enjoyment of the learning process) and student engagement (e.g. fewer drop outs, faster graduation, higher graduation rates) in medical education (e.g. Albanese and Mitchell, 1993; Barrows, 1996; Colliver, 2000; MacKinnon, 1999; Schmidt et al., 2009; Vernon and Blake, 1993). For example, Colliver (2000) concluded that PBL may be more motivating, satisfying and enjoyable for medical students, even if its superiority in test performance cannot be proven (Colliver, 2000). Indeed, PBL allows student groups to solve authentic problems based on prior knowledge and to self-direct and reflect upon their learning. This results to increased motivation and deep learning as opposed to surface learning (Bransford, Brown and Cocking, 2000; Ramsden, 2003; Schmidt and Moust, 2000). Other motivating factors are the relevance of the course content and the degree to which students gain a sense of mastery and autonomy (Deci and Ryan, 2004; MacKinnon, 1999). Bligh (2000) found that methods such as discussions or exercises in class were superior to lecturing in promoting interest in the discipline, for example. This is due to attention problems during lectures – for example student attention declines, lecturer performance falls, students take fewer notes as the lecture goes on and heart rates fall.

All in all, PBL seems to have a positive impact on students' motivation, satisfaction, and attitudes toward learning. PBL students employed more productive approaches to study and found their experience more nurturing, enjoyable, engaging and challenging as compared to traditionally taught students. Students also rate the quality of PBL instruction higher as compared to traditional instruction. They feel more or equally prepared for post-graduate study and practice, while feeling better prepared in terms of self-directed learning and problem solving skills. PBL students and graduates also performed better in terms of interpersonal skills such as communication and teamwork.

Challenges for future effectiveness research on problem-based learning

Overall, the evidence-base on the effectiveness of PBL still needs strengthening in terms of quality and disciplinary coverage (Box 7). In a report on a systematic review and meta-analysis on the effectiveness of PBL in higher education for health professionals, Newman (2003, p. 5) pointed out that "existing overviews of the field do not provide high quality evidence with which to provide robust answers to questions about the effectiveness of PBL". In addition, many studies do not provide sufficient theoretical frameworks for the assessed variables and constructs, data to calculate effect sizes to synthesise the study results and/or description of either the experimental or control interventions (e.g. Belland, French and Ertmer, 2009). Sanson-Fisher and Lynagh (2005) state that research designs and alternative methodological approaches with an acceptable standard of scientific rigour are needed to examine the effectiveness of educational interventions and related contextual factors. Earlier studies also submitted that there was not enough research to draw reliable conclusions (e.g. Albanese and Mitchell, 1993; Vernon and Blake, 1993). Furthermore, major reviews mainly include studies of PBL interventions in health education. Therefore, more research on the short and long-term effectiveness of using a PBL approach is needed (Savery, 2006) – also in fields outside medical education.

Box 7. Issues for future research on PBL

Ravitz (2009) highlights the issues that future research on PBL needs to address:

- Studies must specify how PBL is used in different disciplines and contexts. For example, definitions of PBL in new disciplines and contexts should be varied, more attention should be paid to curricula that call themselves project-based, inquiry-based, design-based, or challenge-based.
- We need studies that inform practice and studies that inform policy. Whilst looking at PBL from a great distance, as in a meta-analysis, it becomes difficult to focus on critical details concerning variations in interventions, comparison treatments, and outcomes. Thus, more studies that look more closely at which specific PBL practices are effective, and ways to improve PBL processes are needed.
- Specific mechanisms that contribute to PBL effectiveness should be identified. Studies often lacked basic information about the type of problems and methods used and relevant information about other types of problems and PBL practices were not available to examine. Hence, there may well be a relationship between PBL method and problem type that we do not know of because of a lack of data.
- Studies should avoid emphasising a false dichotomy between PBL and traditional instruction. Most studies have focused on comparing the effectiveness of PBL versus traditional learning approaches. PBL can take different forms including variations in how much learning is directed by teachers or students within a single problem or across an entire course or curriculum.
- The role of content lectures or whole-class discussions within PBL should be considered. Definitions of PBL frequently indicate that teachers in PBL act as facilitators. Depending on the educational settings, students more often may need to be presented with key concepts at critical junctures during problem solving. In these cases, PBL can be used to stimulate interest in lectures, to make them relevant and meaningful, not to forgo them entirely.

Source: Ravitz (2009)

Moreover, research needs to address better the effectiveness of PBL in promoting a variety of skills for innovation, stressing also the importance of developing assessments for those skills. In addition to subject-based knowledge, the goals of PBL include 21st century skills such as problem-solving, reasoning, critical thinking, collaboration, and self-directed learning (e.g. Barron and Darling-Hammond, 2008; Walker and Leary, 2009). Although assessment methods for students in PBL programmes should be consistent with how students learn (Mennin et al., 2003), most PBL studies include fairly traditional cognitive outcomes of knowledge and knowledge application in medical education. These involve tests using multiple choice formats or assignments measuring the accumulation of knowledge. The use of different approaches to assessment that are more congruent with the goals of PBL is still hampered by methodological and practical difficulties (Boud and Feletti, 1997; Newman, 2003). There is currently a lack of methods for systematically assessing non-technical higher-order skills such as critical thinking or learning skills. Yet, recent meta-analyses and syntheses including different disciplines indicate that studies using assessments that measure application of knowledge and principles favour PBL. The impact of PBL seems also to be most favourable when a wide range of outcomes are measured (Ravitz, 2009; Strobel and Van Barneveld, 2009; Walker and Leary, 2009).

Finally, what is actually implemented in the name of PBL, how and in what context requires clarification (Box 7). The widespread adoption of PBL has produced misapplications and misconceptions about this instructional approach insofar as certain practices are called PBL, but fail to achieve the expected learning outcomes and apply the appropriate methods. Reasons for this situation include, for example, insufficient commitment of staff, insufficient investment in the design, preparation and ongoing

renewal of learning resources, and a lack of research and development on the nature and type of problems to be used (e.g. Boud and Feletti, 1997; Maudsley, 1999). The many forms and flavours of PBL curricula, programmes and courses as well as variances in assessment methodologies make it increasingly difficult to evaluate, compare and generalise findings of studies related to PBL interventions (Mennin et al., 2003). Indeed, Strobel and Van Barneveld (2009) recommend that the research focus should shift from comparing PBL with traditional approaches to studying the effectiveness of specific support structures and strategies of implementation in different institutional contexts including barriers, drivers and challenges of PBL. Also, Beddoes, Jesiek and Borrego (2010) suggest that "new initiatives and studies that strategically and proactively bridge PBL research and practice will likely have the most significant impacts" (p. 21).

NOTES

[1] In many respects PBL is similar to project-based learning. However, project-based learning is considered to be broader in scope than PBL. The latter is often configured as a specific type of project focusing on problem definition and solution strategies (Barron & Darling-Hammond, 2008). While PBL employs specific instructor-designed problems, project-based learning typically requires a negotiation of the learning assignment in terms of goals and deliverables between the students and their project sponsor or client. In project-based learning students work on a project and learn through a series of activities based in authentic, real-world problems. Project-based learning focuses on a problem around which to organise activities resulting in a final project (DeFillippi & Milter, 2009).

[2] For example, Mayer (2004) reviewed studies conducted from 1950 to the late 1980s including research on discovery of problem-solving rules, research on discovery of conservation strategies, and research on discovery of computer programming concepts. The review compared unguided instruction (discovery learning) with guided instruction. Mayer argues that in each case guided discovery has been more effective than pure discovery in helping students learn and transfer: "Guided discovery is effective because it helps students meet two important criteria for active learning: (a) activating or constructing appropriate knowledge to be used for making sense of new incoming information and (b) integrating new incoming information with an appropriate knowledge base" (Mayer, 2004, p. 15).

[3] Walker and Leary's (2009) meta-analysis on PBL builds on former meta-analyses of Dochy, Segers, Van den Bossche and Gijbels (2003) as well as Gijbels, Dochy, Van den Bossche and Segers (2005).

[4] Vote count analysis is reported alongside each finding as a means of more conservatively estimating any observed differences and also to obtain a comparison for the purposes of missing data (Walker & Leary, 2009).

EFFECTIVE TEACHING BEHAVIOURS IN HIGHER EDUCATION

Although PBL can be effective in fostering skills for innovation, more direct teaching behaviours such as lecturing or teacher modelling may also be feasible options for many higher education institutions. Indeed, implementing a PBL curriculum in practice is a long-term process and can have significant challenges regarding both financial and human resources (e.g. Hallinger and Lu, 2011):

- Adequate implementation of PBL can often require tangible resources. The implementation of PBL and the related change process at individual and system level may be more costly than conventional instruction (Berkson, 1993; Colliver, 2000). PBL may be difficult and energy-consuming to implement when class sizes are large or classrooms are not equipped to lend themselves to a PBL format (e.g. movable furniture). PBL also demands staff time, especially in the beginning when instructors must create their own problems for use in the classroom. Bielefeldt, Paterson and Swan (2009) cite institutional difficulties such as resources, programme sustainability, scalability, physical facilities, and management that can hinder PBL implement-ation.

- From the intangible standpoint, the cultural transition of students and faculty from traditional approaches to PBL might also be difficult. PBL involves rethinking of the goals of educational programmes as well as a cultural shift with changing roles of the teacher and the student (Van Barneveld and Strobel, 2009). The implementation of PBL can be expected to require enthusiasm and support. One challenge, for example, is creating strong ill-structured problems that embody the major concepts to be mastered and understood and lead students to realise the intended course learning outcomes (Barell, 2010). PBL can be difficult for both students and faculty "because it challenges them to see learning and knowledge in new ways" (Savin-Baden, 2007, p. 24). Therefore, it is important that faculty who teach in the problem-based learning approach have the appropriate skills as well as opportunities for professional development (e.g. Fukami, 2007).

From the learning science perspective, direct instruction may benefit especially novice learners and direct teaching behaviours are not excluded from PBL approaches either. Also a PBL instructor can provide just-in-time information in a lecture format to facilitate certain instructional goals and adhere to specific contextual factors such as time and space, for example. In order to bridge direct and constructivist instruction and choose an appropriate method depending on the learner and on the context, Rosenshine submits:

> "Instruction in new material begins with full teacher control, and the teacher diminishes control throughout the lesson so that at the end students are working independently. This progression moves from teacher modeling, through guided practice using prompts and cues, to independent and fluent performance by the students. At each step there is a need to monitor student learning, guide student practice, and provide additional support when they need it. But as students exhibit more mastery, the teacher increasingly diminishes control." (2009, pp. 207-208).

This part of the report explores what specific instructional behaviours can enhance the effectiveness of more direct forms of higher education teaching. After a brief look into teacher effectiveness research, the focus is put on identifying specific behaviours that can increase the instructional effectiveness. Finally, the challenges for instructional effectiveness research will be discussed.

Research on effective higher education teaching

Teacher effectiveness research – or instructional effectiveness or process-outcome research – has been primarily done in teacher-centred learning environments that focus on knowledge transmission. Most of the instructional effectiveness research has been carried out in the context of either a lecture or lecture-discussion method of teaching.

Instructional effectiveness research is "the study of relationships between instructional activities of teachers (the processes of teaching), and educational changes that occur in students (the outcomes of teaching)" (Murray, 1997, p. 171). Process-outcome research on teaching behaviours tries to demonstrate empirical relationships between teaching behaviours and student learning and therefore, has been rather a-theoretical in nature insofar as processes underlying these relationships were less researched (Murray, 2007a, p. 158). It differentiates effective teachers from less effective teachers for both cognitive and motivational outcomes based on student ratings and other empirical data sources of teaching performance. As to methodologies, instructional effectiveness research can rely on both correlational investigations based on systematic observations under natural conditions and/or student ratings, and laboratory designs where students are randomly assigned to instructional treatment conditions. Teaching effectiveness research commonly differentiates between multisection validations designs where data from multiple sections of a college course are correlated, and multitrait-multimethod designs where student ratings factors and several criterion measures across a wide range of courses are assessed (Abrami, d'Apollonia & Rosenfield, 2007). For example, Murray's research (2007a, 2007b) suggests that highly rated university teachers exhibit different classroom teaching behaviours than less highly rated teachers. Overall, effectiveness research shows that instructional behaviours are important for student learning, motivation and achievement [1] (e.g. Zeegers, 2004).

In the last decades, instructional effectiveness research has accumulated an extensive body of correlational and experimental evidence on what constitutes effective higher education teaching (for comprehensive state-of-the-art reviews see Perry and Smart, 1997, 2007; Pascarella and Terenzini, 1991, 2005). Effective teaching refers to teaching behaviour that promotes important educational outcomes including knowledge, but also skills such as motivation, and self-concept. There is a broad consensus that teaching and learning are intertwined and that the latter is a function of the former to some extent. There is also clear evidence suggesting that scholarly productivity and instructional effectiveness are largely independent traits (Centra, 1993; Hattie and Marsh, 1996). Moreover, it was found that the pattern of correlation between classroom teaching behaviours and student ratings of teaching effectiveness is quite similar in different academic content areas although interfaculty differences were found with regard to the frequency with which teachers exhibited specific classroom teaching behaviors (Erdle and Murray, 1986).

Although there is no commonly accepted concrete definition of effective university teaching (e.g. Trigwell, 2001), some attempts to depict its main characteristics have been made. In general, research has suggested that successful teachers use a pattern called "direct instruction" or "explicit teaching" or "systematic teaching". As compared to less effective teachers, effective teachers begin their lesson with a 5-8 minute review, spend more time presenting new material and guide student practice, helping students by simplifying questions, providing hints or re-teaching the material. As students exhibit more mastery these instructors decrease control to allow for independent and fluent performance by the students themselves (McDonald and Elias, 1976; Rosenshine, 2009; Stanovich, 1980). In referring to literature reviews Hativa, Barak and Simhi (2001, pp. 701-702) submit that:

> "exemplary university teachers are well prepared and organized, present the material clearly, stimulate students' interest, engagement, and motivation in studying the material through their enthusiasm/expressiveness, have positive rapport with students, show high expectations of them, encourage them, and generally maintain a positive classroom environment."

Based on former research, for example Ramsden (2003) has condensed the knowledge on good teaching into six principles taking students' learning processes into account and enumerating teaching behaviours associated with deep learning (Box 8). He submits that teaching "which is perceived to combine certain human qualities with explanatory skill is most likely to encourage deep approaches" to learning (Ramsden, 2003, p. 74). Research indicates that students who use deep approaches to learning tend to earn higher grades, and retain, integrate, and transfer information at higher rates. Compared to students with surface approaches to learning, students with deep approaches enjoy learning more, read widely, draw on a variety of resources, discuss ideas, reflect on how individual pieces of information relate to larger patterns, and apply knowledge in real world situations[2] (e.g. Biggs, 2003; Ramsden, 2003; Nelson Laird, Seifert, Pascarella, Mayhew and Blaich, 2011). The teaching challenge is then to teach in a way so that most students apply a deep approach to learning using the higher cognitive level processes[3].

Box 8. Six principles for effective higher education teaching

1. Interest and explanation (quality of explanation and stimulation of student interest)
2. Concern and respect for students and student learning (interest in and compassion and consideration for students)
3. Appropriate assessment and feedback (helpful comments on students' work, quality of feedback on students' progress, appropriate assessment tasks)
4. Clear goals and intellectual challenge (high academic expectations, clear structure focused on key concepts, providing interesting challenges)
5. Independence, control and engagement (student choice and control over learning and interest in the subject matter)
6. Learning from students (openness to change)

Source: Ramsden (2003, pp. 93-99).

However, ultimate consensus is difficult – if not even impossible – since what might be understood as teaching effectiveness also depends on contextual characteristics. While these characteristics include for example subject matter, class size, student ability and assessment practices, they vary enormously between departments, faculties and institutions. Complex and ever-changing societal, political, economic, technological and demographic forces also affect what might be understood as effective teaching. The massification, the internationalisation as well as the diversification of higher education influence also what is defined as effective. Hence, effective teaching increasingly involves successful management of the complex context in which learning and teaching take place (Devlin and Samarawickrema, 2010).

Effective teaching behaviours in direct instruction

Instructional effectiveness research in higher education is mostly based on two indicators: (1) student ratings measuring students' satisfaction and (2) student achievement as usually measured by the students' success in the course's tests (see Cashin, 1995; McKeachie, 1979; Marsh, 1987, 2007, for reviews of the student rating literature). The most widely accepted criterion of effective teaching up to date is student learning and the most widely accepted criterion of student learning in instructional effectiveness research is performance on standardised examinations (Marsh, 2007, p. 338). Most of the work on student ratings of teaching effectiveness deals with "behaviours of teachers" or teaching processes but not so much with cognitive processes of the learners. Expected or actual course grade, academic discipline, class size and

grading leniency can also influence student perceptions of teaching – although the influence seems to be small (Pascarella, Seifert and Whitt, 2008).

Overall, positive student ratings and good student performance tend to go hand in hand. Consistently high positive correlations have been found in meta-analyses between students' ratings of the amount learned in a course (with student learning being a measure of good teaching) and course evaluations (e.g. Cohen, 1981; Feldman, 1989; Greenwald and Gillmore, 1997; Marsh, 1987). Research findings indicate that courses with higher exam averages are taught by teachers with higher student rating scores – meaning that more learning as measured by exam scores occurs when instructor evaluations are high. Moreover, it was found that student exam performance correlated more highly with to what extent students perceived the teacher to be clear than with actual (planned) variation of clarity behaviours (Murray, 1997). Evaluation instruments such as student ratings are very reliable outcome measures capturing the data they are set out to capture. Students' ratings capture perceived instructor effectiveness – they are primarily a function of the instructor who teaches the course and not of the course that is taught (Marsh, 2007). Global student ratings – such as overall instructor rating, overall course rating, course materials – are especially suitable for summative evaluation purposes. More specific, multi-dimensional student ratings – such as ratings of course difficulty, feedback, interest/motivation, intellectual challenge, concern for students – are more suitable for formative purposes to facilitate instructional changes and teaching improvement (Abrami, d'Apollonia and Rosenfield, 2007; Weimer, 1997, pp. 418-419).

As to methodologies, instructional effectiveness research can rely on correlational investigations based on systematic classroom observations and/or student ratings and experiments. In the case of experiments, teachers are studied under laboratory or field conditions. In the case of systematic classroom observations, teachers are studied under natural conditions with trained observers visiting classes to record the frequency with which instructors exhibit specific "low-inference" teaching behaviours. Low-inference teaching behaviour is a concrete action of the instructor that can be recorded with little or no inference on the part of an observer such as "addresses individual students by name" or "signals the transition from one topic to the next". In contrast, high-inference teaching behaviour can be assessed only through observer inference or judgment, referring for example to "clarity" or "task orientation" (Murray, 1997, p. 172).

Research indicates that clarity, organisation and preparation as well as expressive, enthusiastic teaching behaviours are strongly linked to instructional outcome measures. Clear and organised higher education teaching is positively correlated especially with student satisfaction as well as with learning engagement and enjoyment. Enthusiastic or expressive teaching seems to be positively linked to achievement, student satisfaction and motivation. Rapport and interaction correlate positively with student satisfaction in particular as well as with motivation, learning engagement and enjoyment.

Clarity and organisation

Teaching clarity and organisation are trainable teaching behaviours that can support the acquisition of skills for innovation. They are associated with specific teacher classroom behaviours such as "using concrete examples", "providing an outline" or "signalling transitions" (McKeachie, 2007). From a theoretical point of view, clarity of instruction can be seen as an important element of instructional effectiveness. Cognitive research suggests connections between instructional clarity – among other dimensions – and cognitive information-processing concepts (Mayer, 1987; Murray, 1997, pp. 181-183). Clarity factors are expected to facilitate meaningful encoding (e.g. structured outlines of the subject matter), connection to prior knowledge (e.g. through concrete examples or practical applications) and storage in long-term memory in the course of information processing. For example, Murray (2007b, p. 193) points out:

> "The underlying process or mechanism whereby teacher clarity facilitates student learning is uncertain, but may relate to the role of underlying low-inference teaching behaviours in structuring information in short-term memory, thus leading to more meaningful encoding of information in long-term memory".

Table 3. Correlations between observed teaching behaviours and student ratings on overall teaching effectiveness

Observed low-inference teaching behaviours		Correlation with student ratings
Clarity	Uses concrete examples	0.47*
	Stresses most important points	0.61*
	Repeats difficult ideas	0.30*
Expressiveness	Shows facial expressions	0.42*
	Gestures with hands and arms	0.38*
	Speaks expressively or "dramatically"	0.63*
Interaction	Addresses individual students by name	0.36*
	Asks questions of class as a whole	0.26*
	Praises students for good ideas	0.36*
Organisation	Puts outline of lecture on blackboard	0.21
	Signals transition to next topic	0.51*
	Summarises periodically	0.17
Task orientation	States teaching objectives	0.34*
	Sticks to point in answering questions	0.22
	Provides sample exam questions	0.17
Interest	Describes relevant personal experience	0.23
	Points out practical applications	0.39*
	Relates subject to student interests	0.19
Rapport	Offers to help students with problems	0.39*
	Announces availability for consultation	0.43*
	Shows concern for student progress	0.54*
Mannerisms	Avoids eye contact with students	-0.38*
	Plays with chalk or pointer	-0.17
	Says "um" or "ah"	-0.19
Speech Quality	Voice fades in mid-sentence	-0.48*
	Stutters, mumbles, or slurs words	-0.44*
	Speaks softly	-0.22*

* Statistically significant correlation ($p<0.05$).

Source: Murray (2007a, p. 150)

Empirical research by Murray (2007a, 2007b) finds clarity to be among the observed teacher behaviours that correlate highly with student ratings on overall teacher effectiveness (Table 3). Clarity in teaching refers to low-inference behaviours such as "uses concrete examples", "stresses most important points" and "repeats difficult ideas". Murray found that 18 of the total of 27 observed classroom teaching behaviours correlated significantly with student ratings of overall teaching effectiveness. Correlations tended to be highest and most consistent for low-inference teaching behaviours loading on clarity, together with expressiveness and interaction – the three factors accounting for 50% to 70% the variance in student ratings of teaching (Murray, 2007a). The six observational studies included in Murray's research had a

total combined sample of 424 teachers and were conducted in Canada. The studies produced a high average interrater reliability of 0.77 and observer ratings of teaching behaviours showed a clear factor structure (Murray, 2007a). The low-inference teaching behaviours seemed to be consistent across situations or contexts in their correlation with overall teaching effectiveness ratings.

Correlational research based on student observations suggests that clarity and organisation are effective teaching behaviours in higher education. Cabrera, Colbeck and Terenzini (1999, cited in Cabrera and La Nasa, 2002) found instructional practices related to clarity and organisation to be among effective behaviours found in engineering education in the United States – together with instructor interaction and feedback as well as with collaborative learning. The results were based on a principal components factor analysis of 20 low-inference teaching behaviours as drawn from research literature. The study included the perceptions of 1 258 engineering students on their instructors. The internal consistency reliability (alpha coefficient) for each teaching dimension ranged from 0.77 to 0.88, alpha coefficients values ranged well above the 0.70 benchmark for scales considered to be highly reliable. More recently, Abrami, d'Apollonia and Rosenfield (2007, p. 429) found clarity, preparation and monitoring of learning to correlate with instructional effectiveness in higher education in Canada. The authors quantitatively integrated the results from 17 correlation matrices and all multi-dimensional student-rating forms that were analysed included global items measuring effective teaching. The factor analysis indicated that there is a "common structure" for instructional effectiveness. Four factors emerged of which the largest ones were highly correlated. "Relevance of instruction", "clarity of instruction", "preparation and management style" and "monitoring learning" were among the categories of the first factor of effective teaching based on student ratings. Some research shows that clarity and organisation are effective teaching behaviours in higher education not only based on student ratings, but also on student achievement in exams. Feldman (1989, 2007) gathered data on student perceptions on characteristics of superior teachers and found that organisation and clarity are teaching behaviours that highly correlated with student achievement in common final exams. The author found correlations between 28 specific instructional dimensions and student achievement in his analyses covering mainly introductory multi-section courses of different subjects in all kinds of higher education institutions in the United States. For instructional dimensions with sufficient information, average product-moment correlation coefficients ranged from 0.57 to -0.11 with all but one being positive and all but three being statistically significant. The two highest correlations explaining variance of over 30% were the dimensions "teacher's preparation and course organisation" (0.57) and "teacher's clarity and understandableness" (0.56). These were followed by "teacher's pursuit and/or meeting of course objectives" (0.49) and "student-perceived outcome or impact of the course" (0.46) indicating between roughly 20% and 30% of explained variance (Feldman, 1997). Feldman suggested that various instructional dimensions are of different importance to teacher effectiveness. His findings were based on a meta-analysis of 46 multi-section validity studies that examined the associations between student evaluations of their teachers and their own learning (Cohen, 1980, 1987; Abrami, Cohen and d'Apollonia, 1988).

Other correlational research suggests that clarity and organisation may improve teaching effectiveness especially with regard to student satisfaction, but the links to other learning outcomes can be less clear. In a five-year project, Murray (1983, 1997, 2007a, 2007b) investigated low-inference teaching behaviours in relation to six learning outcomes (Table 4). The research covered a multiple-section introductory psychology course in Canada with randomly assigned students taught by different instructors (mean section size 182 students, 36 participating instructors). The outcome measures included two measures of student satisfaction (teacher rating, course rating), student motivation (study hours, further course enrolment) and student learning (final exam performance, amount learned rating). All students completed a common final examination as well as standardised course evaluation forms at the end of the course. Murray found that 26 out of the 72 correlations between teaching behaviours and instructional outcomes were statistically significant and that these factors together accounted for 38% to 85% of between-section variance in the various outcome measures. Conceptual clarity was a teacher behaviour factor that correlated positively with student satisfaction measures (teacher and course rating) as well as with

motivation in terms of further course enrolment. Speech clarity and organisation also correlated significantly with student satisfaction measures, but no significant relationship was found with student motivation and student learning measures. Enthusiasm as well as task orientation was positively linked to both student motivation and student learning measures as well as on course ratings.

Table 4. Correlations between teacher behaviour factors and criterion measures

Teacher behaviour factors	Criterion measures					
	Student satisfaction		Student motivation		Student learning	
	Teacher rating	Course rating	Study hours	Further courses	Final exam performance	Amount learned rating
Rapport	0.62*	0.43*	0.14	0.34*	0.27	0.17
Conceptual clarity	0.78*	0.55*	0.20	0.36*	0.16	0.29
Enthusiasm	0.72*	0.57*	0.25	0.45*	0.36*	0.28
Task orientation	0.27	0.41*	0.39*	0.33*	0.38*	0.39*
Organisation	0.34*	0.38*	0.14	0.14	0.25	0.17
Speech clarity	0.64*	0.36*	0.05	0.02	0.29	0.31
Use of class time	0.22	0.30	0.12	0.00	0.41*	0.25
Informality	0.43*	0.42*	0.31	0.35*	0.08	0.29
Nervousness	-0.14	-0.06	`0.13	0.01	0.24	0.35*
Rate of speaking	0.17	0.20	0.33*	0.28	0.31	0.27
Use of media	0.08	0.17	0.11	0.20	-0.23	0.01
Criticism	-0.34*	-0.19	0.01	-0.21	-0.25	-0.20
Multiple R^2	0.85*	0.76*	0.38*	0.48*	0.59*	0.53*

* = Statistically significant at 0.05 level; N = 36 instructors.

Source: Murray (1997, p. 185, 2007a, p. 153).

Indeed, exposure to organised and clear classroom instruction may have positive effects on student satisfaction in terms of decisions to persist at or depart from a particular college or university. A longitudinal study of first-year students at a large research university located in a small midwestern city in the United States found that exposure to organised and clear instruction had a significant positive total effect on actual reenrolment at the institution for the second year of college (Pascarella, Seifert and Whitt, 2008). A ten-item scale was applied to measure a student's reported overall exposure to organised and clear instruction across all of their first-year courses and teachers. The items of organised and clear instruction included organisation of material, preparation, effective time-use, clarity of goals, teacher's content competence, clarity of explanations, use of examples, summaries, interpretation of theories and useful assignments. For the study sample, the internal consistency (alpha) reliability for this scale was 0.91. Data analyses were controlled for an extensive battery of confounding influences and suggested a significant ($p < 0.001$) net impact on first-year student persistence. This is suggested to be an indicator of student satisfaction:

> "Exposure to instructional behaviours that enhance learning (organization and clarity) might also increase the probability of a student's persistence at an institution by increasing his or her sense of overall satisfaction with the education being received." (Pascarella, Seifert and Whitt, 2008, p. 67).

The authors emphasised the importance of classroom instructional practices and teacher behaviours in student persistence at an institution – irrespective of the type of institution attended and despite different

levels of precollege academic preparation (Pascarella, Seifert and Whitt, 2008). These findings were replicated in a longitudinal and multi-institutional study (Pascarella, Salisbury and Blaich, 2011) involving 19 four-year and two-year colleges and universities in the United States.

According to recent research, teaching clarity and organisation also seem to be positively linked to the acquisition of skills such as analytical thinking, ability to consider diverse perspectives or learning engagement. Using regression analysis, BrckaLorenz, Cole, Kinzie and Ribera (2011) researched teaching clarity behaviours related to student engagement, deep learning and self-reported gains in colleges in the United States. They found that students' perception of instructional clarity can promote deep learning as measured with the scales of Higher Order Learning, Integrative Learning and Reflective Learning – showing satisfactory internal validity and reliability. The Higher Order Learning scale included advanced thinking skills such as analysing the basic elements of an idea, experience, or theory, and synthesising ideas or experiences. Integrative Learning scale referred to integrating ideas from various sources, considering diverse perspectives, and discussing ideas, whereas Reflective Learning scale corresponded to engagement in meta-cognitive processes. The study was based on data from the 2010 administration of the National Survey of Student Engagement (NSSE) as well as items from the core NSSE survey. Both first-year as well as senior data were analysed.

Other recent research concurs that especially teaching clarity can have a positive impact on learning engagement and enjoyment (Table 5). Research by Loes, Saichaie, Padgett and Pascarella (2012) on liberal arts students in the United States suggest that instructor clarity is among teaching behaviours that have a positive net impact on both students' Need for Cognition (NFC) and Positive Attitudes Toward Literacy (PATL). Teacher organisation was also positively associated with gains in NFC, but not PATL. NFC refers to an individual's inclination to inquire and engage in effortful cognitive activities and PATL means the extent to which an individual personally enjoys activities such as reading literature, poetry, scientific texts. NFC was measured with an 18-item scale (alpha 0.90) and PATL was assessed with a six-item scale (alpha 0.71). The study utilized data from 49 institutions and over 6 000 first-year students that participated in the Wabash National Study of Liberal Arts Education (WNS, 2006-2008). The results were controlled for race, sex, tested academic preparation, or type of institution attended. A series of multi-institutional studies found significant and positive, although modest, effects of instructional organisation/preparation on standardised measures of higher-level cognitive skills such as critical thinking, reading comprehension, and mathematics (Pascarella, Edison, Nora, Hagedorn and Braxton, 1996). These studies involved first-year students in 18 four-year colleges in the United States.

Overall, empirical research suggests that that clarity and organisation are effective teaching behaviours in higher education. Clear and organised teaching behaviours as observed in the classroom by trained observers or students themselves correlate significantly with student ratings of overall teaching effectiveness. These low-inference teaching behaviours are highly correlated with student learning, i.e. final exam performance and rating of the amount learned, and with other outcome measures such as student satisfaction and student motivation in terms of further course enrolment. More recent studies also found that exposure to organised and clear classroom instruction has significant positive effects on student satisfaction in terms of decisions to persist at or depart from a particular college or university. Teaching clarity and organisation also seem to be positively linked to student engagement, deep learning and the acquisition of skills for innovation such as analytical thinking, synthesising ideas or experiences, ability to consider diverse perspectives, discussing ideas or students' engagement in meta-cognitive processes. In general, these findings seem to be consistent across situations or contexts and disciplines.

Table 5. Standardized effect sizes of teaching behaviours on Need for Cognition and Positive Attitudes Toward Literacy[4]

Variables	Need for Cognition (NFC)		PATL (Positive Attitudes Toward Literacy)	
	General effects	Standard error	General effects	Standard error
Organisation	0.04**	0.02	0.03	0.02
Clarity	0.04*	0.02	0.07***	0.02
Classroom challenge/ expectations	0.05**	0.02	0.08***	0.02
Support	-0.04	0.02	-0.02	0.02
Prompt feedback	0.04*	0.02	0.05**	0.02

*** = Significant at the 0.001 level; ** = Significant at the 0.01 level; * = significant at 0.05 level. Based on Wabash National Study of Liberal Arts Education (n = 6 028).

Source: Loes, Saichaie, Padgett and Pascarella (2012).

Expressiveness and enthusiasm[5]

An enthusiastic/expressive teacher is associated with "vocal variation" "movement and gesture" "facial expression" and "humour" (McKeachie, 2007, p. 463). From a theoretical standpoint, enthusiasm is a key element of instructional effectiveness. For example Marsh's (2007) nine factors[6] combining empirical findings and cognitive research suggest connections between effective instructional dimensions such as enthusiasm and cognitive information-processing concepts (Mayer, 1987; Murray, 1997, pp. 181-183). Enthusiasm factors can serve to elicit and maintain student attention to material presented in class due to elements of spontaneity and stimulus variation. Attention is crucial for all information processing and research indicates that students are more likely to pay attention to teachers who exhibit expressive behaviours.

Correlational research using classroom observations and student ratings suggests enthusiasm and expressiveness to be effective teaching behaviours in higher education. Murray's research (2007a, 2007b) on six observational studies conducted in Canada found enthusiasm and expressiveness to be observed teaching behaviours that correlate with positive student ratings (Table 4). Expressiveness refers to teaching behaviours such as "gestures with hands and arms", "shows facial expressions" or "speaks expressively or 'dramatically'". Together with clarity and interaction, expressiveness was among teaching behaviours that accounted for 50% to 70% of the variance in student ratings and for which correlations tended to be highest and most consistent (Murray, 2007a). Based on multidimensional student-rating forms, the factor analysis by Abrami, d'Apollonia and Rosenfield (2007) showed enthusiasm to correlate highly with instructional effectiveness in Canada. Enthusiasm as a teaching behaviour included aspects of "enthusiasm for teaching", "motivating students to greater effort", "stimulation of interest" and "enthusiasm for subject".

Moreover, research suggests that expressiveness and enthusiasm form part of effective higher education teaching when considering various outcome measures including students' exam performance. In his meta-analysis, Feldman (1989, 1997) found that the instructional dimensions of "teacher motivates students to do their best", "teacher's enthusiasm for the subject" and "teacher's elocutionary skills" were considered to be important for student learning. This was based on student ratings as well as studies reporting views of faculty colleagues or administrators in the United States. Feldman (1989) found that expressiveness was a teaching behaviour that correlated highly with student achievement in common final exams (0.35). In research covering psychology students in Canada, Murray (1983, 1997, 2007a, 2007b)

found that enthusiasm positively correlated with four of six outcome measures included in the study (Table 5). Teacher's enthusiastic behaviour was positively linked not only to final exam performance, but also to taking further courses and student satisfaction measures.

In general, empirical research suggests that enthusiastic or expressive classroom teaching behaviours can serve to elicit and maintain attention and are positively linked to various outcomes measures. Enthusiastic or expressive teaching behaviours seem to correlate positively not only with students' exam performance, but also with student satisfaction and motivation.

Rapport and interaction[7]

Rapport and interaction in higher education teaching can include behaviours such as asking questions, praising students for good ideas, offering help to students or showing concern for student progress. Interaction is one of the key elements of instructional effectiveness from the theoretical perspective. Connections between effective instructional dimensions such interaction and cognitive information-processing concepts are suggested by Marsh's (2007) nine factors combining empirical findings and cognitive research (Mayer, 1987; Murray, 1997, pp. 181-183). Interaction factors are expected to encourage active student participation in the classroom and allow students to actively engage in all stages of information processing. From this point of view teaching is then regarded as helping students to store information and knowledge in long-term memory.

Correlational research based on classroom observations and student ratings put interaction and rapport forward as important features of effective higher education teaching. Both observed interaction and rapport behaviours were found to correlate with positive student ratings in Murray's research (2007a, 2007b) involving six observational studies conducted in Canada (Table 4). Interaction refers to features such as "addresses individual students by name", "asks questions of class as a whole" and "praises students for good ideas" and encourages and rewards participation. Rapport includes behaviours of "offers to help students with problems", "announces availability for consultations" and "shows concern for student progress". Interaction, together with clarity and expressiveness, accounted for 50% to 70% of the variance in student ratings. It was also among teaching behaviours for which correlations tended to be highest and most consistent. Feldman (1989, 1997) found interaction and rapport behaviours to be of moderate importance to teaching effectiveness based on student ratings. Rapport behaviours referred to behaviours such as "teacher's availability and helpfulness", "teacher's sensitivity to, and concern with, class level and progress", "teacher's encouragement of questions and discussion, and openness to opinions of others", "intellectual encouragement and encouragement of independent thought" and "teacher's concern and respect for students". Cabrera, Colbeck and Terenzini (1999, cited in Cabrera & La Nasa, 2002) showed that interaction and feedback are among effective teaching behaviours in engineering education in the United States by conducting a factor analysis on student perceptions on their instructors. The factor analysis by Abrami, d'Apollonia and Rosenfield (2007) showed that interaction and rapport behaviours were linked to instructional effectiveness as measured by student ratings in Canada. More specifically this meant features such as "concern for students" "tolerance of diversity", "availability", "interaction and discussion", "feedback", "respect for others" and "friendly classroom climate".

Recent research suggests also that teaching behaviours related to rapport and interaction are positively linked to student satisfaction, motivation, learning engagement and enjoyment. In researching psychology students in Canada, Murray (1983, 1997, 2007a, 2007b) showed that rapport and informality were positively linked to student satisfaction as well as students' motivation to take further courses, although no significant link with student learning was found (Table 4). A study by Loes, Saichaie, Padgett and Pascarella (2012) on liberal arts students in the United States suggests that prompt feedback is among teaching behaviours that have a positive net impact on both NFC and PATL. This was shown regardless of race, sex, tested academic preparation, or type of institution attended (Table 5).

All in all, research suggests that rapport and interaction as teaching behaviours correlate positively with student ratings, although links with exam performance remain less clear. Rapport and interaction behaviours may have a positive impact on especially student satisfaction (teacher and course ratings) as well as on motivation to enrol in further courses, learning engagement and enjoyment.

Challenges for future instructional effectiveness research

More research with appropriate methodologies is needed to identify what are the effective teaching behaviours also in more student-centred learning environments. In order to investigate whether teaching behaviours identified as effective in lecture-style courses can be shown to be similarly effective with other methods of teaching – cooperative learning, one-to-one tutoring – more research is needed. For example, early studies indicate that interaction and rapport factors overlap to some extent, while other factors significant in lecture-style courses – such as clarity or enthusiasm – were not included in studies investigating small group discussions (Murray, 1997). At the same time, an increasing emphasis on more student-centred courses such as cooperative learning or PBL has made traditional forms of student ratings based on lecture-style courses questionable to judge teaching effectiveness and student rating items as the main basis of research can therefore be inappropriate. They may be biased towards teacher-centred approaches with teaching being evaluated "on the basis of forms designed with the intention of determining if the instructor is a good transmitter of knowledge" (Abrami, Rosenfield and Dedic, 2007, p. 451). In addition, outcome measures not relying on self-reporting such as classroom observations or skills assessments need to be further developed. Although studies have shown that student ratings tend to be very reliable, they sometimes score low on tests of validity.

Research needs to assess the effectiveness of different teaching behaviours against various skills for innovation. Despite the substantial amount of research on effective teaching behaviours, higher education literature on measures of inclination to inquire, lifelong learning, and intellectual development is limited (Loes, Saichaie, Padgett and Pascarella, 2012). The typical cognitive criteria for student achievement underlying teacher effectiveness studies are final examination tests – including multiple choice and/or true/false questions testing declarative knowledge on which students are graded. They tend to assess student learning with regard to lower-level educational objectives such as memory of facts and definitions rather than high-level outcomes such as critical thinking and problem solving. Yet, the way in which knowledge is structured as well as skills and strategies for learning and problem solving are becoming more and more important (Feldman, 2007, pp. 109-110). Students' motivation for learning and cognitive processes are also affected by teaching behaviours – for instance, teacher enthusiasm can enhance student attention, teacher clarity can aid encoding and interaction/rapport can encourage active student participation in the classroom to support deep learning. Due to affordances of a knowledge economy and society an educational objective-shift towards the acquisition of "'adaptive competence,' i.e. the ability to apply meaningfully-learned knowledge and skills flexibility and creatively in different situations" is taking place (De Corte, 2010, p. 45). Thus, new evaluation approaches for formative assessment with regard to various skills for innovation are needed –in addition to summative assessment of different educational objectives.

Finally, research needs to take better into account contextual factors that may impact instructional effectiveness (e.g. Sawyer, 2006). Contextual variables – such as class size, academic disciplines, institutional culture, and students' prior knowledge – are not accounted for in most traditional teaching effectiveness research, although the context also plays an increasingly important role when considering student ratings of teaching effectiveness. For instance, the effectiveness of teacher behaviours related to "organisation" is related to an individual student's prior knowledge, the difficulty of the material and the heterogeneity of the students in class. Thus, the importance of clear and organised teaching behaviours is also affected by characteristics of the teaching and learning context. At the same time, research indicates that there are contextual factors that are more influential than others. Zeegers (2004; see also McKensie

and Schweitzer, 2001), for example, identified students' prior academic performance to be the best predictor of academic success.

NOTES

[1] However, prior academic achievement is considered the primary predictor of current academic achievement (e.g. Zeegers, 2004).

[2] Students who apply a deep approach to learning intend to understand and seek meaning referring to activities that are appropriate to handle the task and to achieve an appropriate outcome. Students who intend to complete a task and memorise information apply a surface approach to learning referring to activities of an inappropriately low cognitive level with fragmented outcomes that do not convey the meaning of the encounter (Marton & Säljö, 1976; Biggs, 1987, 2012).

[3] For example Biggs (2012, p. 40) points out that "'[a]cademic' students will adopt a deep approach to learning in their major subjects, often despite their teaching, while non-academic students are likely to adopt a deep approach only under the most favourable teaching conditions."

[4] Regarding the appearance of relatively small effect sizes throughout the results, the authors state that "it is important to remember that given the fully-specified prediction equations used in each analysis, it is not uncommon to have a relatively conservative estimate of the magnitude of the relationship of any single predictor with the outcome(s) … Accordingly, any variable that significantly predicts either of the outcomes is considered substantive." (Loes, Saichaie, Padgett & Pascarelly, 2012, p. 17).

[5] For methodological details of different studies, see the previous section on clarity and organisation.

[6] Marsh (2007) asked students to rate their best and worst teachers and conceptualised the following nine factors, constitutive for instructional effectiveness: instructor enthusiasm, breadth of coverage, organisation/clarity, assignments/readings, learning value, examinations/grading, group interaction, individual rapport, and workload/difficulty. Marsh and Dunkin's (1997) as well as Feldman's dimensions represent universal items characteristic of all teachers, in all subjects, and at all kinds of institutions.

[7] For methodological details of different studies, see the previous section on clarity and organisation.

CONCLUDING REMARKS

Higher education teaching needs to equip students with a wide range of skills needed in innovative and changing knowledge societies and economies. In addition to subject-based know-what and know-how, this includes skills for thinking and creativity as well as social and behavioural skills. Mastering a wide range of skills will facilitate students becoming true lifelong learners, able to face and act upon the uncertainty of the future. These skills for innovation, together with higher education teaching and learning, are receiving more and more attention worldwide. Based on an extensive body of literature, this paper suggests that teaching matters for student learning. More specifically:

- Compared to more conventional higher education teaching, PBL can be an effective way to develop different discipline-specific and transferable skills for innovation. Research focusing mainly on medical education suggests that students in PBL programmes outperform students in more traditional programmes in applying their knowledge to unfamiliar real-world situations. PBL appears to be beneficial for developing thinking and creativity skills such as critical thinking and problem-solving. It seems to also benefit the development of different social and behavioural skills such as motivation, interest, self-confidence, self-directed learning and teamwork. Research suggests that students in PBL programmes outperform students in more conventional programmes regarding long-term retention and application of knowledge, although no clear difference emerges as to academic test performance. Currently, PBL has been adapted by institutions and educators around the world shifting the curriculum towards a more student-centred and interdisciplinary process (e.g. Barrett and Moore, 2011).

- Considering that adequate implementation of PBL can be costly and difficult in times of tight resources and increasing student enrolment rates, scientific knowledge about the effectiveness of more direct teaching behaviours is also of great value. Instructional effectiveness research indicates that being clear and organised can increase the effectiveness of higher education teaching, as do expressiveness and enthusiasm as well as rapport and interaction with students. Knowledge on effective teaching behaviours can also inform more pragmatically useful and productive gradual adaptations of student-centred forms of teaching and learning such as PBL with regard to local and disciplinary contexts (e.g. Hmelo-Silver, 2012).

Both direct instruction and inquiry learning need to be contemplated in the context of and in relations to educational goals (Kuhn, 2007). PBL can be part of large lecture sections (e.g. Bledsoe, 2011), whilst lectures can themselves be part of PBL. The question for educators is not whether there is a "best" teaching method but what combination of methods is the best for the desired goals when taking into account the different types of students' prior knowledge. In general, some guidance is needed for student learning to occur, although there is disagreement about what amount and kind of guidance should be provided to help students learn. For example, Duffy (2009, p. 358) suggests that for teaching to be effective, the learner must have a need for learning and the instruction provided must be relevant for the learner's sense making:

> "There is a time for telling, but if there is not a need (it is not the time), little will be learned from that telling. The process of learning is one of creating a situation model that allows the individual to interpret the situation in a way consistent with their larger world view – or to modify that

larger world view as, for example, when there is conceptual change. The role of instruction is to support, not direct, that sense making."

More research is still needed on the effectiveness of both student-centred PBL processes and instructional behaviours in higher education teaching. Strobel and Van Barnefeld (2009), for example, call for studies that avoid a narrow dichotomy between PBL versus traditional learning/teaching approaches. The research would need to look more closely at which specific PBL practices are effective by finding "optimal scaffolding, coaching, and modelling strategies for successful facilitation" (Strobel and Van Barnefeld, 2009, p. 55). The topics of interest for future research include:

- The impact of different pedagogies on a broader range of skills for innovation needs further exploration and requires adequate methods of measurement. For example, Schmidt et al. (2009) suggest the inclusion of non-cognitive measures such as self-reported preparation of graduates, study duration or students' satisfaction in the higher education programmes.

- The impact of contextual factors on the effectiveness of different instructional methods – such as class size and culture, discipline, students' prior knowledge and performance – requires more careful and detailed investigation.

- The evidence-base on the effectiveness of PBL still needs to be strengthened and broadened in terms of learning outcomes and disciplinary coverage. More research in disciplines other than medicine is needed.

- In addition to diverse learning outcomes, the evidence-base on effective teaching behaviours needs to be broadened to cover more student-centred approaches. This would help to see whether factors such as clarity, organisation, enthusiasm, expressiveness, rapport and interaction are important when applied in the context of more student-centred teaching and learning.

Finally, while teaching matters for student learning in higher education, so do teachers and their professional development. Faculty plays a pivotal role in enhancing student learning. Instructors can be trained to apply certain instructional behaviours that have been shown to be effective or to use student-centred forms of teaching and learning such as PBL and other methods that facilitate deep approaches to learning. Faculty can learn to give clear explanations and prompt feedback, present well-organised materials, ask students challenging questions, encourage student participation in the classroom and show concern and respect for students and student learning. Indeed, approaches aiming to equip higher education students with diverse skills for innovation cannot neglect the need to equip their teachers with variety of effective teaching skills.

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ANNEX 1. LARGE-SCALE REVIEWS, META-ANALYSES AND META-SYNTHESES FOR PBL

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