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Teaching Complexity by means of Problem-Based Learning: Potential, Practice, and Pitfalls

Lasse Gerrits[a], Martin Wirtz[b]

Abstract: *This paper examines the use of Problem-Based Learning (PBL) in teaching the complexity sciences to students in public administration, policy, and management. We will discuss the background of the method, as well as demonstrate how it is used in some of our courses. We conclude that, while the method is not applicable in every situation, it does perform very well in bridging the gap between concepts and theories from complexity on the one hand, and more mainstream theories in public administration on the other. It performs equally very well in bridging the gap between theory and practice, as such preparing students in developing a complexity-informed approach to policy issues.*

Keywords: teaching; complexity; problem-based learning; public administration

1. Introduction

For about two decades, scholars have argued for a natural fit between concepts derived from the realm of the complexity sciences and public administration, public policy and public management, because such concepts adequately capture the nature of policy problems they are facing (OECD, 2009). As Mary Lee Rhodes and Elizabeth Eppel note in the introduction to this special issue, however, while there is an existing body of literature on teaching public administration (see e.g. the journal 'Teaching Public Administration'), there is virtually no literature on how complexity theory is or should be taught to students in public administration, public policy and public management.

It is self-evident that any teaching approach should help students to learn the content of a discipline, as well as enable them, eventually, to apply their knowledge to real, practical cases (van der Steen, Martijn, van Twist, & Frissen, 2017). Beyond that, the teaching method in question should also display features that make it particularly suitable for teaching a. complexity thinking to b. future public administrators and managers. Classic ex-cathedra teaching is arguably not the best answer to these requirements.

First, the form and content of teaching would not appear compatible (van der Meer, Frans-Bauke & Marks, 2015). If we expect future administrators to engage efficiently in low-hierarchical networks, teachers shouldn't instil a passive stance in students by doing the actual teaching in a hierarchical manner (e.g. Alford & Brock, 2014). Second, the teaching approach should make use of the fact that students, in particular in post-experience programs, bring considerable pre-knowledge (Hall, 2015). Third, related to both of the foregoing points, ex-cathedra teaching with pre-defined solutions to clearly identified problems does not appear adequate to the complex, interdisciplinary challenges public administrators face in daily practice (van der Waldt, Gerrit, 2014).

a Lasse Gerrits, Otto-Friedrich University Bamberg, Germany, E-mail: lasse.gerrits@uni-bamberg.de
b Martin Wirtz, Otto-Friedrich University Bamberg, Germany, E-mail: martin.wirtz@uni-bamberg.de

Fortunately, chalk-and-talk is not the only option for teaching in public administration, even though we can tell from personal experience that this remains a popular teaching method. We also witness many dedicated instructors striving to include more innovative elements in their teaching efforts. This could encompass the inclusion of innovative elements within classic teaching methods, but also more encompassing approaches such as case teaching (Andrews, 1950; Golich, 2000) that serve to restructure the overall format of teaching. The present paper discusses Problem-Based Learning (PBL) (Barrows & Tamblyn, 1980; Schmidt, 1983) as a superior alternative to chalk-and-talk in teaching complexity.

To our knowledge, the diffusion of PBL in the social sciences has so far been limited (Craig & Hale, 2008, p. 165), though it should be noted that some of its elements are also present in other approaches. Maastricht University (The Netherlands) started using PBL in its medical education in 1976 but gradually extended its usage to include the social sciences and the European Studies curriculum amongst others (Maastricht University, 2017; Maurer & Neuhold, 2014). PBL was also adopted by the Erasmus University Rotterdam (The Netherlands), where it was first used in the psychology curriculum, and later on established as the main teaching doctrine for all programs in all social sciences including public administration and policy, and public management (Erasmus University Rotterdam, 2016). In addition, the University of Huddersfield (UK) uses PBL in political science (Craig & Hale, 2008; Hale, 2006). The limited number of social science applications known to us notwithstanding, the experience of the European Studies curriculum at Maastricht University since 2002 and our own experience at two other universities indicates that PBL is a powerful educational tool in our field.

PBL shows considerable parallels to, and sometimes is even used synonymously with, the case teaching method (Hale, 2006). Nevertheless, we focus on PBL here for four reasons. First, PBL can be used for most classes of problems, e.g. practical, theoretical, and some methodological ones. Second, it offers a distinct, clear and effective way of structuring a course and the sessions within the course. Third, it is the method we personally have experience with and have dwelled on also in more theoretical terms. Fourth and most important, we are not intending or claiming to revolutionise teaching in public administration per se, but first and foremost want to explore a teaching method particularly suitable for teaching complexity within the field.

This paper argues that PBL can be instrumental in teaching complexity to students in public administration, public policy and public management. In doing so, the remainder of this paper proceeds as follows. First, we will present the potential of PBL for teaching complexity by pointing out where and how PBL and complexity match. Second, we will present how PBL is applied in practice using the so-called Seven-Step-Approach (Maurer & Neuhold, 2014, pp. 204–207; van Til & Heijden, Francy van der, 2000). We will provide examples from our own experience to demonstrate the approach. Third, we discuss some pitfalls when using PBL, again based on our experiences. We will conclude the paper by identifying PBL as a one promising way of addressing the gap between the awareness of complexity in public administration on the one hand and integrating the respective theories into teaching practice on the other hand. For only if teaching manages to bridge this gap effectively can policy and administration become complexity-informed.

2. Potential

We will first highlight the potential of PBL for teaching complexity theory, largely by elaborating on a number of parallels between PBL on the one hand and complexity theory and/or public administration on the other hand. Naturally, complexity is multidimensional and appears in many shapes to public administrators. While it is useful to dissect the various dimensions (see Gerrits,

2012), we acknowledge that complexity's primary face in the practice of public administration and management comes in the shape of a concrete but wicked problem that begs to be solved. Solving the problems requires one to understand the nature of the problem as expressed in terms of the complexity sciences, i.e. it being systemic, dynamical, emergent, etc. Ideally, knowledge acquired at the academy helps in understanding the problem but this is not as straightforward as it seems: there is a considerable gap between academic knowledge and professional practice (van der Steen, Martijn et al., 2017), and students are often trained to apply abstract and rarefied solutions that – naturally – don't work in a specific case they are facing. A second gap is between the standard concepts and theories in public administration and the ones deployed in the complexity sciences. PBL provides an approach with which these gaps and shortcomings can be remedied.

First of all, PBL was specifically developed in answer to the gap between state-of-the-art knowledge taught at universities and professional practice. H.G. Schmidt recognized such problems both within and beyond his own discipline of medical education leading him to the puzzling conclusion that "people can possess knowledge which they seem unable to apply" (Schmidt, 1983, p. 11). Indeed, this is particularly acute in the medical sector. The theory-vs-practice gap ties in specifically with the complexity of the matter at hand: After all, the human body as the subject of medical studies constitutes a complex system (Sturmberg & Topolski, 2014), and PBL was "established to come to terms with complex problems in the domain of medical studies" (ibid. 2014, p. 199).

In his 1983 article, Schmidt discussed how problem-based learning (PBL) as developed by Barrows and Tamblyn and evolving "out of the needs of professional practice" (ibid. 1983, p. 12) might enable students to turn the knowledge acquired into successful practice. The value of PBL in medical education as established mainly theoretically by Schmidt in 1983 has been questioned within the empirical literature (Kirschner, Sweller, & Clark, 2006), but more recent meta-analyses arrive at an overall positive result (Koh, Khoo, Wong, & Koh, 2008; Schmidt, van der Molen, te Winkel, & Wijnen, 2009).

As we have already noted earlier, PBL can generally be applied in the social sciences, but its success in medical science, as a field characterised by complexity, might imply that it can be transferred even more smoothly to teaching complexity in public administration. In order to substantiate this point, we can further elaborate on the core features of making PBL successful, namely the *activation of prior knowledge, elaboration of knowledge and encoding specificity* (ibid. 1983, p. 12; see also Albanese, & Mitchell1993; Bridges, 1992; Gijselaers, 1996; Schmidt et al., 2009). As we summarise point by point, all of those conditions are generally key to effective learning. They are particularly valuable, however, when applying PBL to teaching complexity in public administration.

The *activation of prior knowledge*, for instance, generally facilitates the memorization and storage of new information that builds on that existing knowledge (Bridges, 1992; Gijselaers, 1996; Maurer & Neuhold, 2014). PBL achieves this by involving all students in a brainstorm on the (as yet undefined) problem situation. The resulting collective formulation of learning objectives then further assures that students are neither bored by having to repeat all too self-evident explanatory components, nor overburdened with questions requiring a degree of knowledge that the students do not yet possess. For teaching complexity, activation of pre-knowledge is important no matter what the composition of the student group: students with professional experience have a rich storage of practical experience, while students following a classic academic curriculum will rarely enter a specific course on complexity without theoretical insights from other classes in the curriculum. In fact, these links have to be established thoroughly in order to ensure that complexity is not understood as yet another intellectual container unrelated to chunks of knowledge already acquired.

PBL then forces students to actively *elaborate on their knowledge* in group discussions. Through these discussion, students often only then start to truly understand what they have just read (Gijselaers, 1996; Maurer & Neuhold, 2014; Schmidt, 1983). Involving students to this extent – both in the activation and elaboration processes – has been considered a paradigm shift (cf. Maurer & Neuhold, 2014, p. 203): Whereas chalk-and-talk follows a positivist epistemology, PBL treats learning as "an active process and social phenomenon that is highly dependent on the context in which learning is taking place" (Maurer & Neuhold, 2014, p. 203). This echoes Morçöl's stance that knowledge generated in the complexity sciences must be understood as contextual. At the same time, complexity science does not deny the possibility of any objective truth (as post-modernists and post-structuralists would). A similar attitude is reflected in the practice of PBL: While "[t]he tutor's [i.e. instructor's] main task is to promote both the learning process of the students and their mutual co-operation" (van Til & Heijden, Francy van der, 2000, p. 16) and to hold himself back, it is still part of his or her role to *control* the discussion, for example by asking questions "if ideas are incorrect" (ibid.). This suggests that PBL, like complexity science, follows a post-positivist, but not (necessarily) a post-modernist philosophy.

In less philosophical terms, PBL involves students by accepting their inputs as relevant and even handing over the organisation of the discussion to a student in the role of a 'chair' (Maurer & Neuhold, 2014; Savin-Baden & Major, 2004; van Til & Heijden, Francy van der, 2000), which by definition is much less hierarchical than ex-cathedra teaching. Addressing complex problems in a non-hierarchical manner is also much more in line with the recommendations for governance that follow from a complexity perspective on public policy making (Klijn & Koppenjan, 2014; cf.Klijn & Koppenjan, 2016).

It is the last of the three conditions for effective learning – *encoding specificity* – where applying PBL in the teaching of complexity seems to carry the highest potential. Encoding specificity concerns the resemblance between the situation in which something is learned and the situation in which it is applied. The higher the resemblance, the better the performance of the students (Schmidt, 1983). Leaving the definition of the problem to students is not just less hierarchical than chalk-and-talk, it is also reasonable to assume that students have to deal with undefined (wicked) problems in their later professional life. Within the medical context where PBL was developed, a problem definition might follow from a patient describing his/her vague symptoms (e.g. Schmidt, 1983, p. 13). Similarly, much of public administration is already concerned with dissecting and then solving what is considered a (societal) problem – be it an untameable budget deficit of a public agency, public roads in disarray after a botched tender, or the introduction of new curricula at public schools not leading to expected results. Once (back) in professional contexts, encoding specificity will ease the application of the knowledge acquired (Gijselaers, 1996; Maurer & Neuhold, 2014; Schmidt, 1983). Note that this doesn't imply that all problems raised need to be real, empirical cases (as applies to the case teaching method, cf. Golich, 2000, p. 12) or purely practical ones. There is also much utility in putting a theoretical problem upfront, provided the instructor can demonstrate how such a question could have relevance in the real world.

Also the ways in which the students are then asked to address the problem resembles administrative practice: rather than being reliably presented with a clear-cut solution by some authority further up the hierarchy, students first have to muddle their way through the information available. In doing so they are – as frequently in real-life – given the opportunity to discuss their approach to a solution in the team, i.e. the PBL group. At the same time, discussing the problem in a team will necessarily involve a degree of disagreement about the 'right' solution. This resembles the kind of substantive complexity (Klijn & Koppenjan, 2014, 2016) public administrators will have to handle in daily practice as well: A rather non-hierarchical network within which knowledge needs to be organised is equally similar to the situation in a PBL class.

Finally, by taking on the role of a 'chair' leading a discussion to a productive end, students probe the role of a network manager. In short, teaching complexity by means of PBL reveals both the content and the process of dealing with complex problems.

3. Practice

We will now present the concrete steps of the PBL process in more detail (for an overview, see Table 2). Throughout the section, we draw from our own experiences in using PBL to teach complexity in various courses within academic programs in public administration, policy, and politics, in Germany and the Netherlands, serving more than 250 course participants in total. The full list of courses is given in Table 1 below. We will use these experiences to substantiate our argument that PBL is suitable for teaching complexity in public administration, as well as provide some guidelines for those interested in applying the method themselves.

Table 1: Overview of courses using PBL to teach complexity as used for this paper. Note that 'Confronting the Urban Crisis' and Socio-technological Evolution' focus on a specific policy domain (urban planning and technology, respectively) but still spend considerable attention on complexity theory and its application to the persistent questions in those domains.

Title	*Period*	*Level*	*Program*	*University*
Dynamics in Complex Systems	2010-2013	MA	Public Administration	Erasmus University Rotterdam (NED)
Theories of Complex Systems	2014-current	MA	Political Science	Otto-Friedrich University Bamberg (GER)
Governance: Theory and Praxis	2014	BA	Political Science	Otto-Friedrich University Bamberg (GER)
Why Things are Complex	2014-current	BA	Political Science	Otto-Friedrich University Bamberg (GER)
Confronting the Urban Crisis	2014-current	MA	Political Science	Otto-Friedrich University Bamberg (GER)
Social-technological Evolution	2015-current	MA	Political Science	Otto-Friedrich University Bamberg (GER)

Preparation

Course preparations focus on designing the 'problem' students will have to address (Gijselaers, 1996, p. 20; Hale, 2006, p. 90; Maurer & Neuhold, 2014, p. 208; Schmidt, 1983, p. 15; Sockalingam, 2010). The problem should be presented in the form of a "neutral description of event or a set of phenomena that are in need of explanation in terms of the underlying process, principles or mechanisms" (Schmidt, 1983, p. 15). The problem needs to be formulated as concretely as possible and needs to fit the degree of complexity students can be expected to handle (cf. Willems, 1981). In practice, there is a wide range of ways for doing it: from problems reported by people working in public administration (Craig & Hale, 2008; Hale, 2006) to entirely self-written descriptions of academic puzzles, such as a text juxtaposing various definitions of 'policy'

as a starting point for a course (Maurer & Neuhold, 2014, p. 211). This raises the question which approach is preferable.

There are pros and cons attached to each approach. The former takes the real-life linkage of PBL most seriously. The latter approach seems much more pragmatic not only in terms of workload (Craig & Hale, 2008, p. 168) but also in terms of flexibility regarding the level of studies, institutional contexts, study programme structure etc. Fortunately, it is not necessary to make a clear-cut decision. First, between those two extremes, there is a lot of space in-between, constituting for instance in the careful selection of relevant news coverage. Newspaper articles often combine a (more or less neutral) description of a real-life situation, while already skipping minor details. Second, there is no reason not to vary the type of problem definitions between various sessions within the same course. In fact, variation of this sort is recommended to avoid monotony (Maurer & Neuhold, 2014, p. 211). In our own practice, we found it helpful to largely rely on self-written problems (also referred to as 'assignment texts', cf. Maurer, Neuhold 2014), so as to maintain coherence between the problem and the materials to be covered for that particular issue. In the following example from the BA course 'Why Things Are Complex', however, we simply drew on a passage from a foreword:

The destruction brought down and across the Japanese coast in March 2011 has returned to us our fear and our uncertainty. We had assumed mastery where misunderstanding and negligence lay. Above all, we have seen the world, and ourselves inside it, brought to cold reflections: How have our systems failed? How have we failed to prevent? How have we failed to imagine? The third charge, our most severe and accusatory, encompasses the whole of our missteps and malpractice towards this disaster and all before it: We may have failed to imagine. Once, requiring only a crude understanding of possibilities and outcomes, wielding technologies of risk was a seemingly simple affair. Their behaviour we assumed to be known, controlled and local. We managed the benefits and risks of these instruments with predictive laws, and thus, predictive remediation when we experience failure. The uncertainties of our technology and its scientific basis were to be uncovered through progress, never beyond the limits of investigation and never included as a feature of science. [Source: Y. Fujigaki (2015). Lessons from Fukushima. Japanese Case Studies on Science, Technology and Society (Foreword by R. Chhem). Heidelberg (et al.): Springer. E-book available at the university library.]

The introductory text then serves as a concrete entry point for reading and discussing academic work. Understanding the literature – here, Perrow's normal accident theory (Perrow, 1999, first published in 1984) – is made easier for students by linking it to a real-world problem they can directly or indirectly relate to. The example here, the Fukushima nuclear disaster of March 2011, is something which most students will personally recall. Such a connection is always necessary to get to grips with the more abstract literature on complexity. It will also help them connect it to previous topics and other literature they may have read, e.g. on the nature complex systems. A problem such as described above will also be used to structure the ensuing group discussion.

New roles of instructors and students

While preparation of the session in terms of problem design and selecting learning materials is the task of the instructor, he/she should focus on facilitating the learning process during what is called the pre- and post-discussion. Instead of the instructor, a student – appointed as chair for a given session – should organise the discussions (for more detailed discussion and/or practical guidance on the roles of instructors and students in PBL, see Savin-Baden & Major, 2004 and van Til & Heijden, Francy van der, 2000, respectively). The learning process is now handed to the students. This corresponds to the non-hierarchical nature of PBL mentioned earlier. In addition to

the advantages of PBL in terms of effective learning that we have noted above, we have found in our own teaching that this shift of responsibility is highly appreciated by many – albeit not all – students: "This feels more like a think-tank than like a normal class", as one student remarked. We concur and see this as a situation that approaches daily practice of administrators. In addition to the aforementioned encoding specificity – indeed think tanks might be where complexity-minded students of public administration might end up – students realise that their inputs are taken seriously and retrieve additional motivation from it.

This change of role doesn't mean that the instructor can remain passive. Indeed, the instructor should ask provocative questions, help in terms of organisational issues and, quite importantly, must pay attention to group dynamics and keep the group from "going off the track", as Maurer and Neuhold (2014, p. 208) put it. This may involve the correction of factually wrong statements as well as the thematic detours.

The seven-step PBL cycle

We will now focus on the actual PBL cycle (see Table 2). Before even hoping to eventually 'solve' the problem within the classroom, the description of the problem as such must be fully understood by all students (Step 1). Amongst others, it must be assured that concepts used in the description provided by the instructor are clarified. This also gives the instructor the opportunity to highlight certain concepts that students may overlook.

Next, the students have to formulate a concise problem statement that becomes the title for the session (Step 2). For example, we discussed the intellectual history of system's theories in the course 'Theories of Complex Systems'. A session about the work of e.g. Forrester or Parsons could focus on the following problem statement: 'Why did structural functionalism in systems theory fall from grace?' Naturally, the statement differs from semester to semester as different students will come up with different suggestions, depending on their reading of the introductory text, pre-knowledge etc.

Having done this, students need to come up with their first possible explanations of the problem, or at least on potentially relevant explanatory elements. This is done using brain-storming techniques involving e.g. a whiteboard (Step 3). Note that this draws primarily from existing knowledge, as well as very tentative – one might even say common sense – ideas from the students. In the example mentioned above, students would often feel that functionalism in systems theory conjured up a rather mechanistic understanding of any complex system – as if such systems could be governed with the push of the button (see Klijn & Snellen, 2009; for a discussion) – and so they would focus on the jargon or normative statements in literature.

Inasmuch as possible, those ideas should then be categorised, structured or set in a relation to each other (Step 4), for example by assigning them to the category of conceptual issues or issues with real-world applications. It can be expected that students will struggle with this because they have yet to delve deeper in the learning materials. However, this struggle has utility as it will make them acutely aware of their own knowledge gaps.

The fifth step, then, is the identification of smaller but more manageable research questions or learning goals. Students can't be expected to formulate these goals according to the standards for academic courses and the quality will vary accordingly. An example comes from the course 'Confronting the Urban Crisis'. Here, the topic of complex systems, and functionalism in such systems, as mentioned above resurfaces in the session on modernism in urban planning. The chair of the session let the students read a text by LeCorbusier. They then formulated the research questions / learning goals as follows:

– Is planning alone enough to change the behaviour of people?
– What is the empirical base for planning in complex cities?
– How can modernist design be implemented properly?
– What explains the popularity of modernism?

Not all possible questions might be equally relevant and it might not be necessary that everyone addresses all of the learning objectives. The group should discuss, therefore, who should address which questions, and, depending on the exact course design, which learning resources are required. In some cases, it may be decided that everyone should address all questions. The instructor could enforce this if there is a risk that students will distribute the work among them with the risk of ignoring some important elements in the learning materials.

Table 2: Overview of the seven-step approach and its underlying logic (source: Maurer, Neuhold 2014 pp. 205-206), added by complexity-relevant aspects

Step	*What to do?*	*What to do in detail?*	*Why?*	*Value added when teaching complexity*
1	Clarification of terms and concepts	Ask for explanations of words or concepts that are not understood If illustration: discuss what picture shows Any sentences/passages that are difficult to understand?	Provide common starting point, i.e. every group member should understand the assignment text as it stands	Linking abstract notions of complexity theory and thinking to real-life experiences of students Facing an *unstructured* problem
2	Formulation of problem statement	Provide *title* for the session or formulate wider research question, i.e. *what is it about*	Students dive into topic and grasp the underlying problem of the assignment By discussing in the group, students establish a common ground of the problem – they not only name it but discuss it and also examine its wider relevance	
3	Brainstorming	Everything is allowed: collection of ideas, potential explanation in regard of problem statement, etc.	To establish and contrast: what does the group already know – what does the group want to find out Students spontaneously name aspects that they consider as interesting and relevant Activation of prior knowledge and real-world experiences – students should link the problem statement to existing knowledge	Non-linear, free-floating process of problem solving
4	Categorising and structuring of Brainstorming	Keywords from Brainstorming are put into similar categories (according to question type; why, how, what consequences, etc.)	Structuring first creative collection of ideas to find patterns and facilitate the formulation of *few* learning objectives	(partial) structuring of complexity
5	Formulation of learning objectives	Use categories of structured brainstorming to formulate single questions or research tasks (e.g. *look for x*)	Provide clear focus in reading the literature by having smaller research questions guiding the learning process Clear and guided assessment of what is needed to answer the posed question	No top-down assignment of tasks
6	Self-study	Students read literature, look for additional sources, prepare answers to the formulated learning objectives	Students as self-directed and responsible learner	Imperfect match between problem (including learning goals) and 'solutions' (information in the literature)
7	Post-discussion and reflection on learning process	Students report back on how they answered the learning objectives, compare results but also exchange arguments Self-assessment of students in learning process and peer assessment, especially in roles of chair and discussant	By formulating acquired knowledge in own words and by exchanging arguments with peers, deeper understanding is facilitated in contrast to pure memorising Students become aware of potential misinterpretations of (empirical) material being confronted with reports from peers By becoming aware of what works well and what could be improved, first step to improve learning process Not all experiences students have to make themselves, but they can learn tremendously by observing and providing feedback to each other	Confronting and managing substantive complexity resulting from differences in the readings of the literature

The fifth step completes the so-called 'pre-discussion' (cf. Maurer & Neuhold, 2014). It is followed by self-study of learning materials in preparation of the next classroom session. This is step 6. Typically, the materials are provided by the instructor. Alternatively, students could be instructed to identify materials themselves. In the course 'Theories of Complex Systems' we asked students to identify and summarize the key elements from certain authors in complexity, such as Holland (e.g. 1995; 2006). This requires that students not only read a text from those authors but also make an attempt to separate the main themes from the minor ones. This is a daunting task for anyone but the students seemed to cope quite well. They would also use secondary materials such as Wikipedia or academic reviews to get a better understanding of the original texts. Authors such as Holland have not only written a lot themselves, others have written about them or used their models in other research projects. Students can get a better understanding of the primary materials through such secondary sources. Authors such as Gerrits (2012) and Morçöl (2012) have given useful overviews of the main concepts and theories in the complexity sciences for public administration and students can use them as reference.

Finally, in the last step, namely the so-called 'post-discussion (cf. Maurer & Neuhold, 2014), students report in the classroom setting how they have addressed the learning objectives, compare their own results and discuss potential differences (Step 7). This is important in science in general but especially important in the complexity sciences where theories can often appear to contradict, overlap or explain the same mechanism using different terminology (see e.g. Morçöl, 2012; on this issue within public administration and public policy).

4. Pitfalls

There are some conditions that are hard to influence for individual instructors, while at the same time they do play a role for the effective application of PBL – as an example, think of the time students can dedicate to a course in the face of obligations for other courses. Moreover, our experience has also provided us with a number of lessons learned concerning some pitfalls when using PBL. We would like to briefly discuss these general conditions and lessons learned here.

There seems to be little doubt that PBL cannot be used effectively in larger groups (>20 students) because such a group size doesn't allow for much direct and interactive discussion among all students. Even below this number, some students might try to 'hide' in the group, thereby avoiding activating their pre-knowledge as well as elaborating on what they have learned in self-study. Generally, smaller groups seem to entail an increased pressure to participate, as students realise quickly that everything depends on them. It should also be noted that we have had good experiences in groups even as small as three students. Nevertheless, it seems that groups of about ten students are ideal, since it increases the variety of insights and opinions without fostering free riding too much.

The institutional setting matters in the performance of PBL, too. For example, the incentive structure in terms of grading may play a role. Ideally, all students participate fully and at high levels without any external incentive. In reality, there will always be a need for an incentive as some students simply want or even need to have their performance graded, or the institutional rules may demand that students can earn grades or credits by deploying certain activities. While some universities have rules that oblige students to participate in sessions and allow for rewarding good performance of both 'chairs' and regular participants in the discussion, others do not even force students to even be present in regular sessions. Nevertheless, there is often some room for manoeuvre within a given institutional structure that can make it more conducive to PBL. For example, we decided to hand out grades for the student chairing a session, leading the discussion and ensuring its quality in terms of form (e.g. involving as many other students as

possible) and content (e.g. covering the learning goals, being led by them rather than the contents of the texts).

Students also need to get acquainted with PBL, which is equally challenging in both form and content. This is independent from the composition of student groups. Students – at least the ones we encounter in our classrooms – are primed for chalk-and-talk, either through high school experiences or because of lectures followed elsewhere at the university. Even post-experience students can be difficult to guide at first, given that their work experience has primed them in certain ways and has created some mental path-dependency. Here, the instructor must take care to keep the discussion open, e.g. by asking critical questions. Generally, it helps students if the instructor does not only formally present some 'rules of the game' for PBL to which students can refer, but if he or she also leads by example in taking over the role of a chair in the first session.

In addition, whatever the external conditions, instructors should seek to avoid a number of pitfalls. The most basic pitfall is to assume that PBL sessions would be less demanding for instructors because students are supposed to take control of the sessions. Holding yourself back as an instructor doesn't mean leaning back. Balancing between holding back and trying to keep control is one of the main challenges (Hale, 2006, p. 92; Maurer & Neuhold, 2014). It may be tempting, for example, to intervene in the learning process by leading the pre-discussion as an instructor and to shape learning goals in order to make them match the assigned literature. Here, as well as in the post-discussion, it is necessary to be careful not give students the impression that their involvement is just window-dressing. In one of our own courses, providing pre-defined learning goals after having students read the 'problem' led the students to conclude that the text outlining the problem was just some way of linking two sessions. This is not undesirable per se, but a far cry from the activation and usage of prior knowledge.

Last but not least: Our experiences with fitting PBL into a given institutional setting have taught us that the Seven-Step-design of PBL should not be changed – it is designed to be used in this way and we believe that it is the best way to structure the sessions. For example, the course 'Dynamics of Complex Systems' originally used elements from PBL but not in the exact order as prescribed in the seven-step approach. While this could still make a viable course, it doesn't benefit from the activation of the mechanisms PBL is aimed at. After all, it is not just a way of organising a session, but a way of making sure that the benefits of PBL in terms of activation of pre-knowledge, encoding specificity and elaboration are actually reaped. Similarly, in the course 'Why Things are Complex' we adopted most but not all elements from PBL in the expectation that this would ease BA students into this type of learning. Instead, some students got confused about the actual purpose of the method. In the following semester, we added even more elements of PBL, but left the instructor in control of the pre-discussion. This, in turn, made students feel that they were supposed to guess the learning goals the instructor wished to hear. In most cases, it is possible to integrate PBL within one's teaching environment. When deciding in favour of PBL, our experience shows that it is then better to go for it wholeheartedly, This means, first, to adopt as much of the framework and mind-set presented above, and, of course, not to give up after the first round, as group dynamics will change from seminar to seminar.

5. Conclusion

Our experience with PBL in teaching complexity has been very positive so far. Student surveys, which have been collected after each course, show that a majority of the students value the format. They report that they have experienced a steep but manageable learning curve, and that they can relate the new knowledge to knowledge already obtained. In addition, they report that they see the relevance of the understanding knowledge for solving complex real-world issues. Asked in the

qualitative section of the evaluation form what should be kept the same about the course, "PBL" is regularly named. Most importantly, students agree or even fully agree to the statement that "Teaching methods employed are well suited to the subject matter". Naturally, it is very difficult to measure the long-term impact of using PBL in these courses. Whether it helps students to later apply complexity thinking in their work after graduation is something that needs to be researched. In any case, our practical experience so far does not contradict the theoretical arguments made in the first sections of this paper. Hence there is reason to believe that PBL helps in bridging the gaps identified in the introduction to this paper, and that it helps students to comprehend theories and concepts from the complexity sciences, and to relate it to more mainstream concepts and theories from public administration.

Teaching complexity theory to students in public administration, policy and management is highly relevant, but there is little guidance on how to do it. Without excluding all other innovative teaching approaches, we have suggested Problem-Based Learning (PBL) as deserving consideration. We discussed the origin as well as applications of PBL and presented the main steps of the approach using examples from our own course. While we will not claim that PBL is always the best method in any setting, we do believe that it is a powerful way of overcoming the gaps between the complexity sciences and mainstream approaches in public administration, and between theory and practice. Based on the match we perceive in terms of the mind-sets behind PBL and the complexity sciences, respectively, as well as the feedback we receive from using PBL in practice, we hold that that it is one promising method in teaching of complexity in public administration.

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