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Evaluation of different Project Based Learning designs in an MSc degree

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Abstract
The design and implementation of different Project Based Learning (PBL) approaches are presented in this paper. All of them were carried out in the framework of the MSc degree in Electronic Systems for Smart Environments from the University of Malaga. Four subjects were developed using different values of the three main parameters of PBL: teamwork, self-guided learning and project complexity. During two academic years, several indicators were used to evaluate these experiences: compliance with subject time schedules, scores obtained for the students, interaction of each student in his team and satisfaction of students with the experiences. Our results encourage the use of PBL in bachelor degrees but, at the same time, confirm that PBL implementation is not a trivial task when projects are complex or when a high level of autonomous learning is required from students. Teamwork difficulties have also been found. So, we discuss the need of reaching a minimum level of proficiency in some key competencies before using PBL.

Keywords
Project based learning, teamwork, self-guided learning, MSc degree.

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1. Introduction

Convergence towards the European Higher Education Area has led students and instructors from teacher-centered to learner-centered approaches (European Communities 2009), such as Problem-Based Learning (PBL). However if Biggs' 3P model (Biggs 1993) is assumed, new teaching strategies –especially those not thoroughly experimented– should be adopted with precaution. In the 3P model, outlined in Figure 1, the students' presage variables have influence both in the learning process and in the learning product. But product and process have also impact on presage variables: what students experience in current learning processes will have an influence on how future learning is confronted. Careless design or application of a teaching-learning method can compromise not only learning outcome, but also the students' future attitude towards the method.

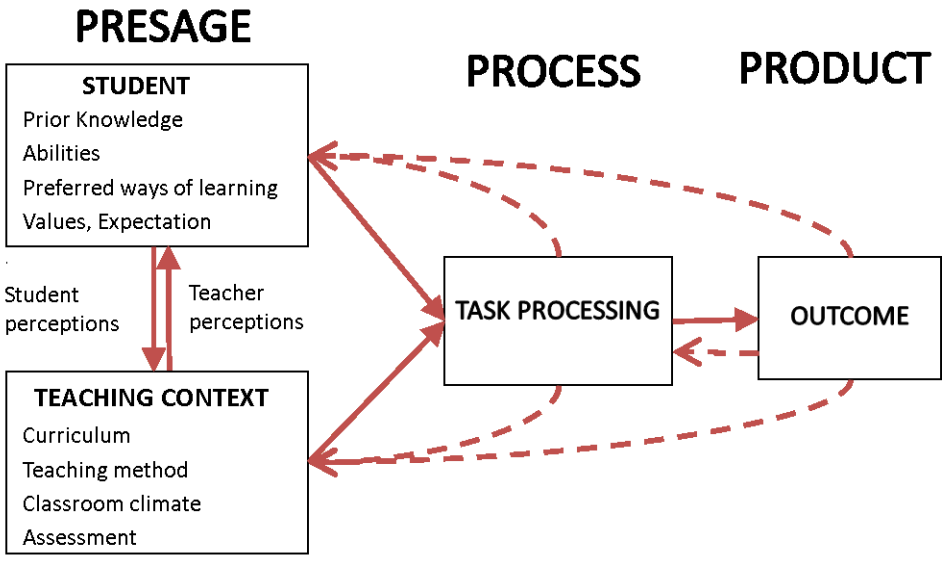

Figure 1. Biggs' 3P model

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This work was motivated by the will to experiment PBL, a strategy that was new to the authors. The aforementioned precautions led them to choose a context with few, highly motivated students. Specific courses within the MSc degree in Electronic Systems for Smart Environments[1] (MESSE) from the University of Malaga were chosen to put the method in practice. These are described in Section 2.

1.1. Parameters for PBL design and evaluation

In PBL, learning is structured around a problem or a project as similar as possible to those encountered in professional settings. The students solve the problem or realize the project, which is formulated at the beginning of the teaching-learning process. Aside from the guiding project, the fundamental ingredients of PBL are individual self-directed learning and group work (Chikotas 2008). Successful application of PBL has been extensively described (Fernández Martínez 2006), although some authors have reported issues with acquisition (Perrenet 2000) and evaluation (Dym 2005) of specific skills, and with the necessary change of mindset required from students and from teachers (Spronken 2009). This work will also look at issues that arise in the application of PBL when several design variants are considered.

Let us start by considering teacher intervention. In its more radical form, which we can call 'pure' PBL, traditional lectures are not used. Students self-organize their own learning, which is driven by the need to solve the guiding problem. The teacher's role is that of moderator and partner in the process. In a less radical approach, the teacher guides students towards the solution more or less explicitly (Savery 2006). Lectures might be used, for instance, but only after students have worked on the problem.

[1] http://www.masterseeiuma.es/

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According to Savery (2006), teacher intervention should be minimized if the students are to build their own learning, which is something that the ECTS system of the European Higher Education Area seems to promote (European Communities 2009). However, development of technical skills in the curriculum is also expected, especially those linked to regulated professions (Boletín Oficial del Estado 2009). This in practise means that specific subjects must be covered, and a compromise must be made between PBL-style self-guided learning, and more traditional teacher-guided activities.

Previous work has put PBL in practice at different levels, from experiences limited to a single subject (García Almiñana 2006) to degree-wide implementations (Enemark 1994). Application at wider levels allows formulation of more complex problems, which is in line with a ´pure´ PBL approach. However, this requires a high level of coordination among several teachers, which can be a challenge.

Finally PBL, which is rooted in social constructivism (Chikotas 2008), requires from students a high degree of cooperation. Thus, the challenges of teamwork are also present in PBL. An overview of these challenges and possible approaches to successful group work is given in Felder (1994).

The main parameters for PBL design and evaluation are depicted in Figure 2. Elements described in this section are shown as input parameters. The teacher must choose a specific level of each one for a specific PBL design, taking into account the technical skills of the student before the PBL activities take place. The outputs that should be observed to assess the successfulness of the process are shown too.

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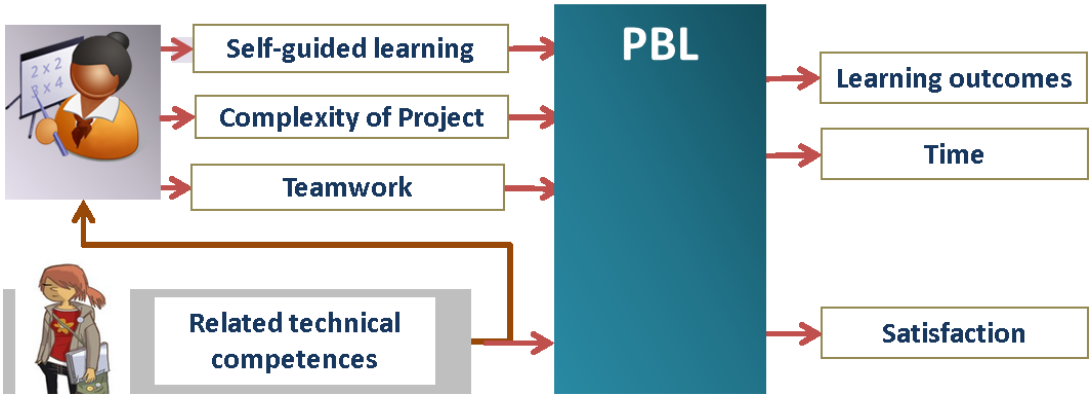

Figure 2. Parameters for PBL design and evaluation

1.2. Objective and phases of work

We used and evaluated some of the variants of PBL described in the previous section, within the scope of the MESSE, in order to investigate the applicability of the methodology and, where appropriate, to extrapolate the results to the new academic degrees. It should be clarified that it was not our objective to test the hypothesis that PBL improves the quality of teaching because we are aware of the many uncontrollable variables (student profile, thematic subjects, faculty profiles, etc.) that would prevent us from drawing any conclusion about this regard.

This work was carried out during two academic years under the framework of an Educational Innovation Project at the University of Malaga. Moreover, this project also proposed a basic development of entrepreneurial competency in the same MSc degree. Specific details regarding its design and evaluation can be found in García-Berdonés (2012), although this competency will also be mentioned here because of its use of PBL.

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To achieve the objectives of the project, two working phases were proposed in a cycle of design-test-redesign-test. Thus, in Phase I, corresponding to the 2010-11 academic course, the learning activities were designed and the results were analysed. Phase II repeated the process for the 2011-12 academic course, incorporating the redesigns advised by the results of the previous phase.

The organization of this document is as follow. In the next section, there will be a brief description of the university degree and the subjects involved in this work. The following two sections describe the phases of the project. Finally, the conclusions and future directions for this work are presented.

2. University degree, subjects and students involved in the study

The MESSE is an official MSc with 60 ECTS, offered by the Telecommunication Engineering School at the University of Malaga. Its goal is to train students in how to plan and develop electronic systems that are usually part of so-called smart environments. Competences related with user-centred design and data processing techniques, both useful in this type of environments, are also developed. The MESSE began to be taught in the 2009-10 academic year. Therefore, the work presented here was carried out during the second and third editions, affecting the teaching of 15 and 8 enrolled students, respectively, in each of the editions. All the subjects involved in this work are compulsory and they are described below.

Methodology for planning, management and development of projects (MET), with six ECTS, aims to familiarize students with the work methodologies for project management, with a focus on quality. Also, this subject fosters an entrepreneurial competency. PBL will be used to achieve both goals (MET.Quality and

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MET.Entrepreneurs). *User Interfaces* (UI), with three ECTS, proposes that students are able to analyse and evaluate the usability and accessibility of a user interface. PBL is applied about usability. *Advanced Information Processing Techniques* (AIPT), with three ECTS, aims to introduce students to computational intelligence techniques that are useful in the design of intelligent environments. PBL is used to help students to delimit the applicability of each technique. Finally, *Master´s degree Thesis* (MT) is a twelve ECTS subject that intends the student to plan, design and implement an electronic prototype for a smart environment. Master´s degree Thesis is considered as a project. Therefore, its design and planning is proposed as the guide project for the PBL associated with MET.Quality.

3. Design, implementation and results of Phase I (Academic year 2010/2011)

3.1. Design of learning activities and indicators

For each of the learning experiences, Table 1 summarizes its PBL design parameters, which are detailed below, and the main planned features for group activities, following Felder (1994).

Regarding the *Project*, in MET.Entrepreneurs students are invited to prepare a business plan for an idea related to the subject of MESSE. This plan has to be exposed to a guest entrepreneur by the students during the course. In MET.Quality, students aim to design and plan their MT, which should begin immediately after the end the course. AIPT raise the solution of four different problems that mimic/simulate actual problems. Students have to solve these problems using several computational intelligence techniques. UI intends to evaluate the usability of a remote control for a hotel room. The students

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should design the control system before they know the usability principles that will be explained later. The MT subject was not involved in this first phase.

The *degree of self-direct learning* that will be required to the students will depends of the scheduled time to develop each competency as well as the specific skills that students will need to complete each PBL. The contents associated with MET.Entrepreneurs are very new to the student, and due to limited time, students will afford the design process in a guided way, with lectures at the beginning of most of the programmed activities. Although autonomous work is required to complete this activities (students need to read texts and to find information), this work is guided (pre-selection of texts, using templates). Meanwhile, UI has a constructivist approach which takes advantage of the student preconceptions about usability, criticized in successive sessions and in a final discussion in group. Again, due to time constraints, students receive lectures that guide their reviews.

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Table 1. Main characteristics of the four PBL experiences

	MET. Entrepre.	MET.Quality	AIPT	UI
Duration (ECTS)	1,5	4,5	3	1,5
Teamwork activities	3	6	4	2
Dependency among activities	Sequential	Sequential	Self-contained	-----
Number of activities that begin with lectures	2	0	0	1
Level of Complexity of the project	**Average**	**High**	**Average**	**Average**
Level of Self-guided learning	**Low**	**Average**	**High**	**Low**
Level of Teamwork	**High**	**High**	**High**	**Low**
Teamwork: Number of team members	3-4	3-4	2-3	3-4
Teamwork: Team formation	Random	Assigned MT	Random	Random
Teamwork: Positive interdependence	High	Void	Void	High
Teamwork: Individual accountability	Low	Low	Low	Low
Teamwork: Face to face interaction	Average	Average	Average	Average
Teamwork: Operating reflection	Void	Void	Low	Void
Teamwork: Appropriate use of collaborative skills	Documen tation	1 guided session	Void	1 guided session
Weight in the final score: Teamwork activities / individual examination	20%/10%	30%/40%	70%/30%	0/100%

The contents of AIPT are also novel, but it is estimated that there is enough time to follow the philosophy *first problem - then lecture*. Thus we decided to provide students with little theoretical basis before facing each problem. With respect to the previous knowledge of the student about a particular problem, MET.Quality is between UI and AIPT, and it proposes a design with the same philosophy of AIPT, but with a single, longer project. Teachers guide students in the realization of this project, dividing it into four blocks of linked activities. The output of a block is needed to start the next. Each

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block consists of three phases. In the first phase, the students must work autonomously to develop a solution to the problem, starting from a base material that is provided by teachers. In the second phase, a group discussion is performed where each student presents his or her particular solution. The ultimate aim of this phase is to agree on a joint solution. In the last phase the students present and discuss in class all the solutions developed by the groups. The teachers have previously reviewed these solutions. Between phases 2 and 3, some lectures are included in order to complement the initial provided information.

Regarding *teamwork*, the teams at AIPT and MET worked during the whole course, whereas at UI they only worked two days: one for preparing the proposal at the beginning of the course, and other one, at the end, devoted to the concluding debate. The work posed to teams at MET.Entrepreneurs and UI forced a distribution of tasks among its members, while in the other two cases all teams' members worked together on a common subject. In all cases, a classroom time was reserved to carry out the group activities, thus ensuring face-to-face interaction. Pressure for completing the syllabus of course caused that no time was scheduled either to reflect on the progress of the team works or to learn new techniques to improve their performance.

Finally, the following *indicators* were used to assess the performance of each PBL: degree of compliance with their respective schedules (output Time in Figure 2); scores obtained by the students (output learning outcomes in Figure 2), and the degree of satisfaction of students (output Satisfaction in Figure 2) collected through individualized surveys carried out by their assigned tutors. Information on teams´ operation was also considered because of their importance for a successful PBL. This indicator was obtained by observation of team classroom activity and, in some cases, analysing team web forums.

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3.2. Results and analysis to redesign

All activities were performed in accordance with their *scheduling*, except at MET.Quality. From the second block of activities, the discussion phase was not held in half of the teams, due to their members having reached dissimilar level of learning. Thus, each team performed this task at a different pace, and some of them had to do a substantial amount of work outside the classroom. This work was added to the individual tasks, necessary for the next block. The result was that students definitely quit these delayed tasks, prioritizing the final team works (which are considered for the final score). Furthermore, the lectures were lengthened more than planned, which resulted in a decrease in time available for teamwork into the classroom. All these circumstances, in addition to the pressure for covering the syllabus of the course, made the previous study and discussion to be replaced by lectures in the third block (at least, that led, as a positive effect, to the synchronization of learning among the class-team). The phase of oral presentation was also removed and substituted by teacher feedback on the written deliverables.

No major problems were registered in the teams' operation, except for MET.Quality, where two extreme problems occurred: on the one hand, a group was disengaged from the rest, delivering the task outdated and signed by only one or two of its members; on the other hand, the most active group was blocked by clashes between its leaders. Both issues were successfully overcome because the rating does not solely rest on the group's tasks (see table 1). The use of the forums was very polarized: some groups used them very intensely while the rest seldom used them.

The collection of information about the *degree of satisfaction* with the development of subjects among students had not worked well enough due to coordination problems between tutors. However, we could detect a certain degree of demotivation with the

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subject MET and some complaints about the timing of activities in several subjects, producing punctual, but relatively frequent, peaks of workload.

Regarding *student scores*, all students successfully overcame subjects, although a significant dispersion among scores of members of the same group was observed.

4. Redesign, implementation and results of Phase II (Academic year 2011/2012)

Regarding *PBL designs*, no changes were included excepting in PM.Quaity, where PBL was abandoned, moving that philosophy to the Master´s degree Thesis subject. Students are allowed to work as a team in a common part of their master thesis: the design and implementation of a basic prototype, leaving as individual work to make some improvements to that prototype. Nevertheless, students could do the whole work alone if they wanted. In addition, teams did not share a common schedule anymore. A timetable was established for students to work (individually or as a team) supervised by their professor, who only advised them about the way to follow depending on their previous approaches. Furthermore, some activities were included in order to increase student motivation in MET (e.g. analysis of an invented story about a failure due to lack of quality management) and subject timing was changed in order to improve the coordination among them and minimise peak workload reported by students.

In Phase II, the same *indicators* than in Phase I were used, together with a web survey and a structured interview to get satisfaction of students with the subjects and teamwork. Also, a questionnaire about roles within the team was also adapted and administered (Gómez Mujica 2003).

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Regarding *results*, all the subjects were on *schedule*, but most of students complained about MET.Entrepreneurship because of lack of time to do the proposed activities. Students did not blame this to the work demanded by other subjects. Therefore, it can be said that, firstly, coordination among subjects has been improved thanks to structural changes carried on and, secondly, that keeping the self-learning level (not increasing autonomous activities) was a right decision, because it avoided problems with the schedule.

This academic year, students also succeeded in all the subjects, although a high deviation among individual rates of component of each team was again observed. The degree of *satisfaction* with the subjects is high, but comparable with the rest of subjects not involved in this project.

Analysing *results* in more detail, no problems were detected with *group performance in the classroom*. Out of it, students reported as a drawback member's availability, especially for those students who combined their studies in MESSE with other professional activities. Nevertheless, these problems were not blocking, as students reported a high degree of *satisfaction with teamwork* as well. Finally, student's profiles for teamwork roles was very homogenous among both, students and roles. Hence, there was no useful information there.

Summarizing, involved subjects obtained very similar results in both years, excepting PM.Quality, where significant problems were not detected during the second year. For the master thesis subject, it was observed that students worked at very different paces and, although they worked as a team at the beginning, they gradually changed to work individually, due to problems with availability, as reported themselves. Only one group kept as a team until the end and they reported in both, their master thesis dissertation and defence, that teamwork was very useful.

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5. Conclusions, considerations and forthcoming works

Firstly, it is very important to notice that the implemented PBL designs have been, in general, conservative in the sense that none of them was compliant with the features of a *pure* PBL, as it is described in the introduction. The less conservative experience, MET.Quality, has been the more difficult one and, finally, professors were headed toward the withdrawal of the planned design, at the middle of the first year. Nevertheless, this experience allowed us to see a possible problem in our design: the attempt to synchronize randomly composed teams during a long period. It is possible that students do not work together suitably, or even if they do it, their learning-process work-rate was different. The obtained results with the Master`s degree Thesis subject confirm this idea.

Moreover, it is important to show that there are also several experiences with less problems than the MET.Quality subject, the UI and AIPT ones. These subjects have achieved an important simplification in their design related to the project complexity, the required self-guided learning or the demanded teamwork. In the same way, the time problems in the MET.Entrepreneurship subject probably could have been reduced, if we had used a more conservative PBL design with a more guided experience.

The project chosen for MET.Quality was not sufficiently motivating. Furthermore, MET.Quality is a low-tech subject, and thus the students' motivation is *a priori* low. The motivation mechanisms developed during the second year, rather unrelated to PBL, produced better results, although it was impossible to finish them because of the students' different profiles.

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Finally, the obtained dispersions within the scores of member of each group show that the developed evaluation mechanism is not suitable for this matter; see García Berdonés (2012) for more details.

Taking into account all of the above, it would be better to develop, in the Bachelor degrees, a set of experiences with very relaxed requirements in, at least, one of the input parameters in the PBL design; or, even better, within the range of some motivating subject for the students, without taking into account the PBL as a motivating element. In addition, as it was described in the introduction, the design stage may be implemented with special emphasis. About this matter, some considerations will be shown below.

Problems that students have reported (difficulties to synchronize the activities of groups and failures observed in some of them) could be explained, at least in part, by the diversity of the students' preparation about several factors: prior knowledge, self-guided learning capacity or ability to work efficiently within a group (i.e., the teamwork competency).

It is convenient to remark that, from the social constructivism (Chikotas 2008), PBL proposed working group learning (teaching methodology) and not learning to work in groups (competency development). Therefore, although PBL is often described as a teaching methodology that develops generic skills of self-guided learning and teamwork, in our opinion, it is more accurate to say that PBL *uses* the level the student has in both competencies, and increases that level. Returning to the Biggs' model presented in the introduction, we can venture that if the PBL design does not conform to the level that students have in both competencies, they may develop animosity towards them, rather than a higher level of domain. It would be a way to acquire the so-called accidental incompetency in Walther (2007). This does not mean at all that with PBL it is not possible to develop generic competencies. Rather, it means that the PBL design

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requires a careful thinking about all the students' capabilities, and not only on specific competencies, as usual. In this sense, this conclusion is fully consistent with Felder (2005). Figure 3 depict these reflections by extending the Figure 2.

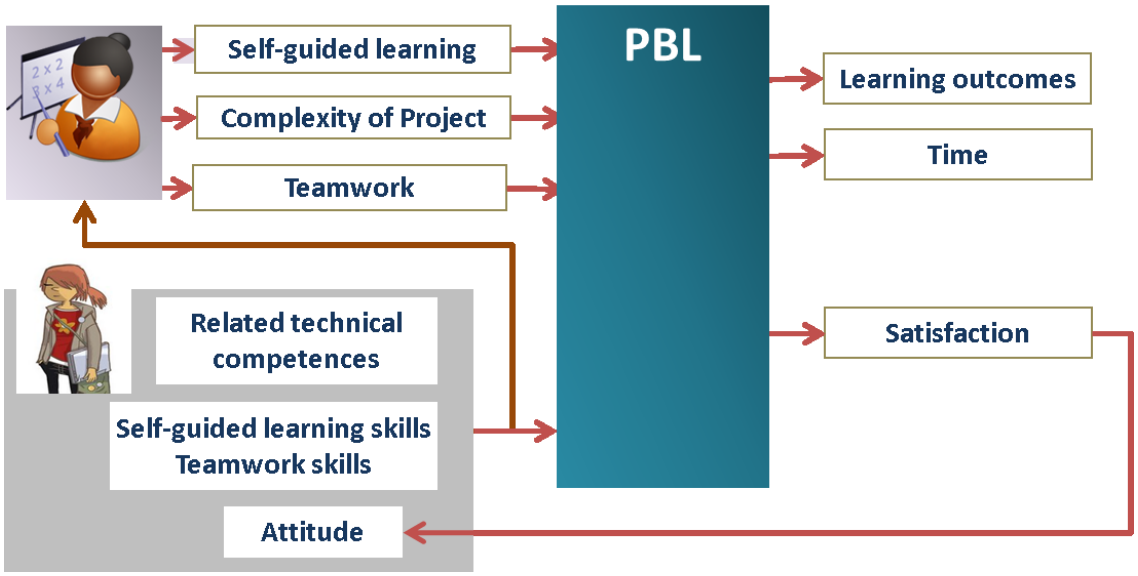

Figure 3. New parameters for PBL design and evaluation

The experiences presented here lead us to think about some questions that go beyond PBL. If generic competencies are necessary to use PBL (or to observe law requirements or to carry on a successful professional activities), would we know how to develop them? In addition, would we be willing to invest time in it at the expense of subtracting time from specific competencies? Our experience cannot answer these questions because in all our designs, the specific agenda has dominated and almost no time has been reserved for generic competencies training. In our opinion, to answer these questions is a very interesting line of future work.

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