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Starter Activities for Systematic Identification of Learning Outcomes by Students: A Process from Design to Evaluation

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Abstract – Higher educational programs increasingly rely on project-based learning. In 2003, our engineering school reorganized its curriculum by incorporating large semester projects into. However, soon thereafter, it appeared that several students struggled to identify the intended project's learning outcomes and therefore tended to distance themselves from it. In response, we decided to clarify students the outcomes from the outset of the project to give them a clearer understanding of the knowledge and skills they were expected to acquire and cultivate.

Considering that short team concrete experiences could advantageously help students recognise by themselves learning outcomes, in 2004, we began inserting half-day starter activities in the front-end of each of our 100-hour semester projects. Properly designed starter activities can give students deeper insights into the skills and abilities required to better complete the project and associated learning, promote enthusiasm, and increase project involvement and participation. For program developments or reform purposes, this paper proposes a three-phase design to evaluation process of such starter activities to ensure coherent treatment throughout a curriculum when educational staff's skills are heterogeneous and/or pedagogic responsibilities are shared.

Index Terms –learning outcomes, project-based learning, starter activities, student participation, continual improvement.

INTRODUCTION

Student experimentation of professional skills is a key goal of engineering education. To enhance student competencies, post-graduate schools increasingly resort to experiential learning [1] as a pedagogical tool. Several leading engineering schools have recently adopted project-based learning approaches (PjBL) [2] as part of their syllabus (e.g. the CDIO™ initiative [3]). In 2003, our school reorganized its ICT engineering education program by incorporating large PjBL experiences in its curriculum [4]. To obtain our standard three-year engineering degree, students must now complete four semester long projects averaging 100 hours each per student, during their first two years. Such projects

typically involve about 200 students split into teams. Almost immediately, we faced the following problem: several students have difficulty identifying the project's desired learning outcomes (LOs) [5] and only slowly become involved and functional within the project's context. Moreover, in our national educational environment, a new engineering student's prior experience is usually limited to traditional teaching models (cf. selective French preparatory school with lectures and exercises before becoming integrated into a *Grande Ecole*). The PjBL approach may therefore be unsettling for the student. For these reasons, we considered it advisable to disclose the intended learning outcomes [6] to the students as soon as possible in order to give some meaning and significance to their projects and learning.

While traditional course materials typically list what learning is expected, these LOs are often not read or understood by the. To introduce project-specific LOs to students in a more effective way, we began to systematically introduce half-day concrete group experiences in 2004. Conducted at the outset of each semester's 100-hour project, these starter activities prepare students for the following large project experimentations. This paper explores the benefits and organizational challenges of incorporating such activities. It promotes a three-phase process, from initial design to evaluation, which ensures coherency among the various courses through careful LO harmonization.

This paper is structured as follows. In the first section, one of our starter activities is presented as an example. Next section explains our three-phase process for starter activity design, deployment, and evaluation. Following section exemplifies the first design phase as used for integrating a starter activity into a semester project. Then, an analysis based on questionnaires and tutors as well as students less formal feedbacks is presented. After discussing process refinement and examining the limits of LO alignment, the final section concludes and proposes avenues for future investigation.

A STARTER ACTIVITY APPLIED TO TWO PROGRAMS

Many exercises have been designed to promote team work or expose students to scientific, technical or business skills. Icebreakers, kick-offs, warm-ups, energizers and brain-teasers are often used in group activities [7]. In engineering

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education, instructors use such kind of practical games with increasing frequency. For example, Polytech Singapore has proposed a One-Day One-Problem™ framework confronting students to a problem designed to generate problem-solving skills [8]. At the end of the program, a facilitator presents a solution to the problem and students are encouraged to present their own proposal. At MIT, short active learning games are introduced as activities to support formal classroom education [9]. In physics, the highly competitive International Bridge Building Contest [10] challenges high school students to construct a small bridge under strict conditions. Contestants are graded based on the structural efficiency of the bridge they built.

In this section, we describe a three-hour starter activity and its application to two programs. In this well known short mission, a team of students [11] has to build a small bridge between two tables that must further permit an object to autonomously cross from one table to the other. Such a mission can be adapted and used as a warming-up game, or as an introduction to project management courses and team management activities. For intended project management LOs, some quality-cost-schedule constraints are introduced during this activity, for instance:

- To fulfill quality requirements, the learners must only use components listed in a given catalogue (e.g., rope, straws, marbles, matches, sheets of paper). Also, the tables are exactly positioned at one meter from each other, and the link must be static during the demonstration;
- Cost and delivery are fixed for components. A virtual (but controlled) restrictive budget is granted for covering the development and valorization fees. Each component has a specific price and delivery time after its order (e.g., marble in 45 minutes, one meter adhesive tape in 25 minutes). Each team is responsible for managing its orders at the store as well as the delivery conditions. The timeframe may be voluntarily tight;
- During the activity, the learners have 30 minutes for discovering the mission, preparing the first steps of the design, filling a simple management plan (an outline is provided), possibly ordering the first components, and delivering a five-minute presentation of their proposal. During this rapid presentation, the students present their management plan, team organization, and a diagram of their proposal to a fictional customer. Then, a period of 45 minutes is granted for purposes of ordering and waiting for materials, building the link, testing and promoting it. Finally, a ten-minute oral defense is scheduled for purposes of presenting the solution brought to the mission, with a light poster and the product demonstration.

Most often, such missions are used as short PjBL concrete experiences. Our starter activities follow such type of missions, but are closely interlinked with the following courses or large projects. Depending on several parameters, e.g., the teachers' intentions, the audience concerned, and/or

the institutional context, the mission and its frame can then be adjusted (e.g., periods, formality and level of constraints, deliverables). For example, in our institution students come from more than 40 different countries. If desirable for LOs purposes, intercultural aspects can be included by the starter activity designers.

We integrated the above bridge mission into a 21-hour project management course in a Master of Science in Syria, and in a professional continuing education program. The activity is then more used as an icebreaker and a sensitizer to the project management basics. Some typical situations observed by the instructor during the activity are fruitfully gathered to emphasize specific points about project management practices during the following course.

In a larger context, a bridge starter activity is also implemented in our 4th semester project entitled "S4-Engineer's Project", involving approximately 30 teams of seven learners, during 110 hours (one project per team proposed by industrial partners or alumni clients). As a general rule, during the design phase of a new mission, we address the milestones to be followed in the coming project which reflect the main phases of a V-shaped lifecycle model [12], including the project management tasks. But, above all, we attempt to underline the project intended LOs. Accordingly, the starter activity of the S4 project was carefully designed to shed light to the new LOs expected (e.g., being able to (i) apply a project management method in order to guarantee furniture compliance with cost, quality and schedule issues, (ii) organize, share tasks and responsibilities within a team, valorize productions). Immediately following the starter activity, a systematic student team debriefing, supervised by a tutor, aims at increasing and accompanying reflection [13]. In practice, when embedded in a large project unit, the tutor merely acts as an observer, grasping indicators of proficiencies, with a view to clarifying LOs for students rather than facilitating their resolution of the mission. In particular, individual as well as team strengths and weaknesses are discussed with students in relation to LOs, so as to develop a more reflective comprehension [14] and abstract conceptualization of the required skills. The activity also promotes enthusiasm and motivation, and thus increases involvement and participation.

For our project framework [4], it proved necessary to establish guidelines for designing and managing such starter activities, so as to ensure better coherency and quality, and to analyze how they contribute to help students identify and interpret LOs by themselves.

FROM DESIGN TO EVALUATION PHASES

In this section, we describe our starter activity engineering process as adapted for projects or courses. It is suitable for engineering schools as it may be adjusted to different domains or audience. The process greatly benefited from tutors and learners feedbacks concerning starter activity deployment since 2004. For the sake of clarity, only the

core process activities¹ are reported herein. More detailed tasks are addressed in the examples described in next sections.

We recommend following three consecutive phases named *Design*, *Deployment* and *Evaluation* (cf. Figure 1). Each phase is composed of sequential activities A_i , where actors have dedicated roles and responsibilities. Constraints C_i , associated with some activities, allow adapting them to specific contexts (e.g., student cultures, following project or course, team, room or lab size, planning). Some activities may result in datasheets to be used for future activities by students or tutors.

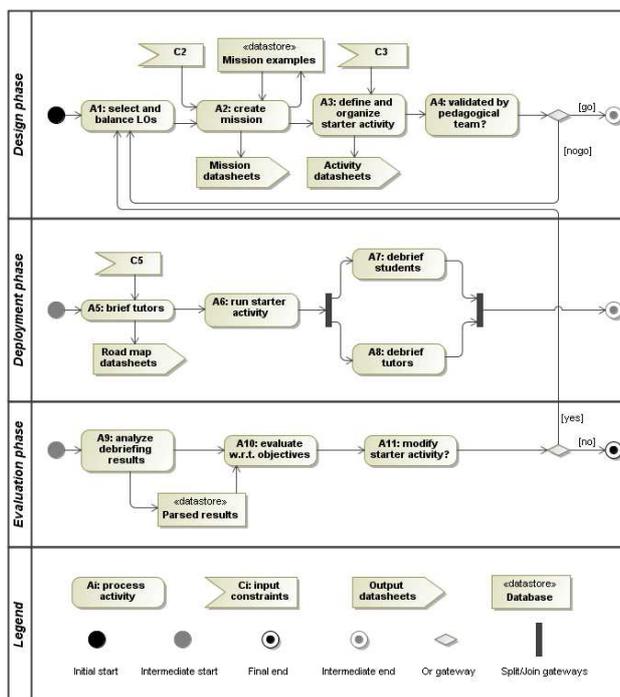


FIGURE 1

FLOW DIAGRAM FOR DESIGNING, DEPLOYING, AND EVALUATING STARTER ACTIVITIES.

I. Design Phase: A Mission to be Embedded in a Course or Project

The *Design* phase consists in selecting or defining a starter activity adapted to specific LOs, and results in a dedicated mission. During the first activity A_1 (cf. upper left part of Figure 1), designers must select some LOs in order to link the concrete experience with observable competencies of the upcoming course or project. These LOs must be carefully weighed so as to obtain a proper balance among them. The designers must then create a mission (A_2) according to these LOs, possibly by adapting or combining existing ones stored in a database (fed by former activities or found in common repositories of group activities exercises, e.g. [7]). For efficiency purposes, the mission must be both pleasant

(motivation) and unsettling for learners (engagement and learning). Also, cognitive obstacles must be anticipated and adjusted according to the learners' profiles (cf. input constraints C_2 , e.g., sense of practicality, risk taking, team work experience). Activity A_2 results in a proposed mission datasheet including the various actors' views and describing the main elements of the mission. Those mission datasheets are then to be calibrated and enriched with extra parameters issued from C_3 input constraints (e.g., planning of the session, materials and scholar logistics, cross-presentation to be made by the students, one or two teams with a unique tutor per room) to define and organize the starter activity (activity A_3). This part of the *Design* phase requires many output deliverables: starter activity description roadmap, reflection sheets for students, observation and debriefing sheets for tutors, and general activity organization such as scheduling and team selection. The last activity A_4 of the *Design* phase consists in a review by the pedagogical and academic teams for validation purposes as well as for favoring holistic coherency within the curriculum. A *nogo* decision as regards activity A_4 prompts designers to go back to one of the three former activities, depending on where improvements are requested to fulfill the reviewers' requirements (e.g. A_1 in the Figure).

II. Deployment Phase: Briefing and Debriefings

After a *go* decision at the end of the previous phase, the *Deployment* phase starts with a tutor briefing (A_5), in light of their roles during the starter activity vis-à-vis students. This briefing restates the main starter activity intentions and insists on the most important aspects of their task: e.g., most often strictly respecting the time, accurately observing the learners' behaviors and skills of the learners, and properly conducting the students' debriefing with a view on LOs. Tutors may have various profiles (as possible constraint C_5): in our institution, they are scientists, language teachers, or Ph.D. students. When the mission actually starts (A_6), the students are faced with technical points or team organization issues depending on the intended LOs. As an example, in the bridge mission for the S4 project, the debriefing period for learners (A_7) lasts 30 minutes per groups (previously, each student has filled a questionnaire before sharing opinions) and is conducted through questions which may be divided in four categories: (i) team organization (e.g. "have you arranged the allocation of tasks and responsibilities among the team members?"), (ii) production (e.g. "are you able to justify why your solution is adequate considering the mission requirements and constraints?"), (iii) communication within the team (e.g. "did you propose a solution to the other members which was not considered?"), and, finally, (iv) preparation of the large semester project experimentation starting immediately thereafter (e.g., "have you already established a first plan for your semester project milestones and/or contact your future advisors?"). A debriefing of tutors (A_8) is also to be conducted after the starter session (possibly just before their student debriefings and/or after student debriefings).

¹ Activity is introduced herein as the term employed for business process modeling.

III. Evaluation Phase: Preparing Continual Improvement

Based on feedbacks from students and tutors, this last *Evaluation* phase must validate the effectiveness of the approach, i.e. that it properly induced students to identify the following project or course LOs. For instance, program leaders must assess whether (i) the activity favors students' reflection, (ii) the mission was sufficiently pleasant and motivating, and (iii) the time-frame was appropriate. To this end, data collected through tutors' and learners' debriefings are quantitatively and qualitatively analyzed (A9), and stored in a database for future comparative evaluations (A10).

The last, but not least, gateway activity (A11) consists in determining if starter activity must be reengineered. At the end of this phase, for quality assurance management purposes, the workflow should redirect to the *Design* phase, possibly inducing modifications of activities A1, A2 or A3 depending on the weaknesses or failures observed. At this stage, a *no* decision would depict a hypothetical stable perfection.

STARTER ACTIVITY DESIGN PHASE FOR A SEMESTER DEVELOPMENT PROJECT

In order to exemplify our process, this section presents, step by step, the first process phase as applied during one of our semester projects extended with a starter activity. This 100-hour build-test project, entitled "S2-Development project", consists in developing technical products within a scientific discipline of one of our research laboratories (e.g., electronic, image and information processing, computer engineering, optics, microwaves, networks). The last weeks of the project are devoted to writing a technical report exposing the results obtained and methods applied, so as to improve the future maintenance and evolution of the system or prototype developed. In this project, students are divided in smaller teams of three to four persons. The project LOs include technical abilities (e.g., to be able to design and implement a technical solution, to assess elements of a solution, to apply an appropriate solving methodology) and transversal abilities (e.g., to supply a product efficiently and in time, to write a technical report collaboratively, in accordance with specific quality criteria).

In 2006, the starter activity designers (five members for this mission) strictly followed the *Design* phase:

- **Activity A1:** Students participating in this S2 project (one full day per week over the semester) are freshmen in the second semester. Most often, due to their background, they have very few genuine previous experiences in the technical area, but are generally motivated and eager to practice. In addition, they are largely unfamiliar with development lifecycles. Their various stages are generally difficult to identify without prior experience and conceptualization, and, especially, the stages following the implementation phase (i.e. tests and validation), as well as the drafting of technical documents (which needs scientific and technical clarity for texts and models, precision, conciseness and

compliance with specific rules like formats and figures). Consequently, the designers selected the following LOs: (LO1) to design and implement an original technical solution with its validation tools and (LO2) to write a technical report.

- **Activity A2:** According to the intended LOs and cognitive domains, the designers decided to promote a new exercise rather than adapting an existing one. Among other, considering student profiles in constraints C2 and LO balance, the exercise had to demand low technical skills, favor imaginative ability, and be as pleasant as possible. The corresponding mission consisted in the design and implementation of a board game. Its technical solution had to comply with accurate instructions (meeting LO1). Thereafter, the students were demanded to create the rules of their game (meeting LO2 and parts of LO1) and to collectively write an evaluation grid composed of at least ten precise criteria relating to the validation stage (e.g., always a winner, termination of the play, fairness of gamers). Finally, the game and written documents had to be assessed according to the evaluation criteria.
- **Activity A3:** Due to constraints C3 (e.g., three-hour max, low availability of tutors at that time), it was decided that the future mission would be divided in three stages: (i) mission reformulation, (ii) deliverables development, and (iii) cross-validation (two groups of students per classroom). Then, individual student questionnaires were defined, including, for example, the following questions: "Do you dedicate enough time to finding ideas?" (creativity and work organization), "Could you justify the quality of your game prototype?" (reasoning), and "Are your test criteria, properly quantified?" (validation and theoretical models). After the usual reflective team debriefing, it was planned that each team would complete the work task allocation among its members for the upcoming semester project. Note that the chosen activity structure reflected some classic milestones of a development cycle with its test stage.
- **Gateway validation activity A4:** Finally, the designers presented their results to the heads of the S2-project and to the pedagogical team. The aims, objectives, and approach were then defended and justified. Note that the game topic selection (i.e., telecommunications, institution discovery, or professional project of students) had been left to these project leaders who, finally, opted for a game whose stake was for new incoming students to discover the campus.

RESULT ANALYSIS

Our approach contains a final *Evaluation* phase aiming at supporting the activity effectiveness vis-à-vis project leaders. Such phase is also essential for managing continual improvement.

I. S2-Project Starter Activity

For the first year “S2-Development project”, an initial analysis was conducted. Feedbacks came through an anonymous and voluntary questionnaire submitted to students during three consecutive years, at the end of the semester project (346 answers retrieved via the Moodle learning management system, each time five months after the starter concrete activity). They were also obtained through informal discussions among students immediately after the debriefings and thanks to tutor debriefings.

Only 57% of the replying students answered positively to the question “Were the objectives of the activity clear?” and 76% replied negatively to “Was the starter activity helpful for your project?”. This seems to show that, after some time has elapsed (five months), students do not clearly identify the original starter activity intentions. These results may also point out the strenuous challenge of the reflective debriefing [15]. In addition, some students stated that the activity was interesting, but not serious enough. For example, one of them considered that “the activity is useless because it is merely a ridiculous role playing game quickly completed in two hours”. Consequently, depending on students’ achievement levels, we now advise our tutors to dynamically adjust the feasibility constraints during the mission in order to add or lower complexities, galvanize cognitive obstacles, and thus strongly induce students to identify areas of learning improvement as regards personal or collective skills. In light of the feedbacks which cover our four projects since 2004, it is now clear that overall students’ satisfaction is still not the main strength of our starter activities.

Nevertheless, our analysis reveals that our starter activities lead to some tangible benefits. First, during the experience, students are sufficiently motivated and creative to imprint a team dynamic on the upcoming project. Second, debriefings improve a short-term identification and understanding of specific project LOs by the students.

II. Objectively Assessing Intended Learning Outcomes for Evaluation

In our institution, the *Evaluation* phase is still informal as it is based on discussions and subjective questionnaires conducted at the end of each project. In order to determine more objectively whether the intentions of our starter activities are achieved or not, neither the tutors’ feedbacks, nor the students’ perceptions prove to be sufficient due to the halo effect.

After a few years of experimentation, for a continual improvement loop (initiated by gateway activity *A11*), a thorough and rigorous verification is necessary. Traditionally, assignments and examinations are used to assess the knowledge and abilities acquired by the students (e.g. disciplinary knowledge). When based on concrete experiences or active experimentations, some of these skills may be difficult to measure [16], and therefore to objectively assess (e.g., intercultural team work, problem solving, initiative, creativity, affective attributes). In PjBL, the appraisal of the domain of a LO typically requires to place

the student in a new practical situation. For assessing the short term impacts and persistence of concrete starter activities, it would be useful to examine the student’s skills and abilities within a team, at various key stages of his/her semester project. What are his/her cognitive domains before and after the activity for each LOs? A new practical active exercise just after the student debriefing could help determining if the LOs have been properly perceived, interpreted and understood. During the project, which may last a whole semester, were the concepts materialized, applied, and transferred? Did the student’s skills increase over time (or decrease)? An additional short practical activity at the end of the project would perhaps allow replying these questions more objectively.

DISCUSSION

I. Process Refinement

Some of our process activities, as well as flows, could be refined for specialization purposes in other contexts (e.g., institution size, student’s profiles and autonomy).

For example, in the *Design* phase, a new flow could be promoted when the pedagogical team and dean defend a *nogo* after *A4* as in Figure 1. In fact, it is not always necessary to rebalance the LOs, especially when the proposed mission is considered too complex for students (e.g. technical or problem solving skills, required inductive reasoning or team profiles or cultures) or does not satisfy disciplinary knowledge prerequisites. In such case, only the mission could be adjusted or changed by selecting a new one in the database (i.e. redirection to activity *A2* despite of *A1*).

Tutor expertise dimensions are also to be considered. The tutor may influence students too much (e.g. Pygmalion effect), although he/she should act as a mere solver or blocker (e.g., helping or coaching students, dynamically relaxing or increasing hard feasibility constraints). If the tutor is explicitly aware of the LOs and intentions, he/she should only provide the necessary elements to students so as to introduce reasonable cognitive obstacles. When debriefing with a team, he/she should act as a facilitator of reflection [14]. For this reason, the tutor-briefing activity *A5* of the *Deployment* phase is of primary importance. This constraint (e.g. tutors’ profile and experience) could also be emphasized as an input proficiency element of the *Design* phase in *C3*.

II. Limits of Learning Outcomes Alignment

Our starter activities aim at increasing students’ comprehension of their project educational program. In the cognitive domain, in reference to the pyramidal Bloom revised taxonomy [5], the remembering category is generally satisfied in the short term (i.e. the student is able to list the main new LOs of the forthcoming project) and, sometimes, comprehension is achieved (i.e. the student is able to describe and illustrate the LOs of the forthcoming project). However, analyzing and evaluating domains are rarely reached right after the short concrete experience (e.g., self-

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estimate his/her performance, how LOs relates to his/her future professional activities). Thanks to the reflective debriefing, simple and obvious connections are made by students, but their significance for the next coming project is not so easily grasped.

Moreover, in experiential learning, the learning style inventory of Kolb [17] has showed that a student's individual learning preferences could be specific (e.g., converger and pragmatic, accommodator and activist, assimilator and theorist, or diverger and reflector). The need to clarify intended LOs depends on such profiles. This may be the reason why some students tend to view these activities as games not really connected to concepts and to the associated larger project experimentation. Accordingly, it would be useful to recognize such profiles as evolving constraints in our process.

CONCLUSION AND FUTURE DIRECTIONS

To give some significance to learning, it is advisable to have students identify and interpret, by themselves, the intended learning outcomes. For this purpose, we systematically propose a starter concrete experience before exposing engineering students to our semester large projects. Reflection, with the assistance of a tutor, may help students to conceptualize and put into perspective the subsequent activities of the program. In order to encourage institutions and pedagogical teams to investigate learning outcomes identification through experiential learning, we have proposed in this paper a process aiming at uniformly designing, deploying and evaluating such starter activities. The data, roles and work tasks of the stakeholders are clarified, step by step, in alignment with course or project intended learning outcomes.

Learners need to face technical challenges and managerial complexities that represent first cognitive obstacles. If properly designed and handled, a starter activity induces a greater awareness of the strengths and weaknesses of expected skills and abilities. However, the practical feasibility of a mission should be dynamically controlled in order to ensure a positive reinforcement and maintain a minimum contentment and motivation. After some years of application, our core intentions, i.e. clarifying through these concrete experiences the intended learning outcomes for the students, still show some flaws. In the context of our semester projects, it is now clear that the number of learning outcomes addressed should be limited so as to remain clear as it only represents a half-day experience including a short 30-minute debriefing.

Our starter activities definitely favor an effective students' team work and a better understanding of the milestones of the upcoming project. Moreover, they permit tutors to early point out possible weaknesses within teams (e.g., relational and intercultural problems, organization) and therefore to warn the next project instructor or supervisor to pay more attention during the subsequent project. Repetitive student weaknesses as to a specific skill throughout the curriculum can also be revealed through those activities.

Until now, in our institution, tutors' feedbacks are informal and not systematic. We plan to generalize them in the close future. In addition, in order to scientifically validate the better identification by students of learning outcomes thanks to our approach, a more rigorous analysis is to be initiated in our process through a controlled experiment on test groups.

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