FRAMEWORK FOR PROJECT-BASED TRAINING PROVIDED TO FIRST-YEAR STUDENTS OF MATHEMATICS

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ABSTRACT

This paper presents a proposal of a framework for project-based training provided to first-year students of Mathematics. This model has been piloted with first-year students of Informatics at the Faculty of Mathematics and Informatics at Plovdiv University "Paisiy Hilendarski". It is argued that such an approach boosts students' motivation and raises their awareness both of the subject matter and of their prospective career opportunities.

I. INTRODUCTION

There has been a steady trend over the recent years for a decline in the interest in Bachelor and Master degree programs in Mathematics both in Bulgaria and worldwide [1]. Mathematics graduates tend to pursue careers largely in the field of information and communication technologies and services [ibid.]. As a proactive response, some of the undergraduate students undertake two degrees simultaneously, as the second is either in Informatics or Business studies. However, in order to be competitive beyond their own field, mathematicians need some extra knowledge and skills to supplement the ones strictly related to their major field of specialization. An opportunity FMI offers to supplement the compulsory fundamental knowledge is the system of eight elective courses throughout its 4-year Bachelor program in Mathematics. To meet this demand, we propose a framework spanning over two modules of 60 contact hours each, for a project-based training designed to be provided to first-year students of mathematics. It could be implemented under different forms, e.g. an elective course or interdisciplinary approach in teaching another discipline, e.g. Information Technologies.

II. SOME BENEFITS OF PROJECT-BASED LEARNING

During our long-year experience with project-based teaching techniques, we have observed a synergetic effect resulting from the empowerment of the learners whose motivation and degree of autonomy is boosted within meaningful activities they are involved in. As this has been dealt with in detail in the literature, we are not going to elaborate any further, but it will suffice to mention just a couple of the main points. The project-based model, combined with problem solving, provides new challenges to the inquisitive students of mathematics whose satisfaction grows with every step along the learning ladder. While "there is a problem with no predetermined answer", there is also "an atmosphere that tolerates error and change" [2]. This is an essential part of the learning experience that will bear relevance in the future academic and working activities these students will be occupied with. Another important feature is that "students design the process for reaching a solution" [ibid.]. This facilitates the shift in the teaching paradigm whereby the learning process becomes learner-centered. However, the transition to autonomy is not a binary state, nor does it take place overnight, but is rather a multidimensional continuum affected by a large number of internal and external factors for both trainers and trainees [3].

Project-based learning leads to "increasing social and communication skills" [4]. Interaction with peers and instructor takes place in more meaningful and natural settings. One of the outcomes is that students are better prepared to handle the real-life situations on their potential workplaces not in terms of ready-made solutions, but rather in terms of skills required for problem-solving and team work.

III. A PROJECT-BASED FRAMEWORK

We suggest that this framework be applied in the first year of study because in this way we would smoothly bridge the gap between the secondary school IT training and the IT course in the Bachelors program in Mathematics in the second year in FMI at Plovdiv University. Besides, this is the time when essential learning habits, skills and styles are shaped and will be used in the future. The time frame is flexible and can be adjusted to other contexts, not necessarily within the 2 trimesters x 10 weeks format as in the pilot course. In our case, this framework was designed to supplement the major course, but this is not a mandatory limitation and it can be used as a self-contained course module in its own right.

TABLE 1. Project based learning framework: module 1

#	ASSIGNMENT	Guidelines	Week
	MODULE I (e.g. Trimester A, or Elective 1)		
1	**Multimedia presentations on negotiated topics**	List1	1

1.1	Designing and developing the file of the presentation	1.1	1
1.2	Delivering the presentation in class	1.2	2
1.3	Developing a photo album to illustrate the topic	1.3	2
1.4	Compiling a Glossary of terms related to the topic (based on a core textbook, desktop research, etc.)	1.4	2
1.5	Peer evaluation and discussion of the implementation of 1.1 and 1.2; negotiating revision criteria for both development and delivery	1.5	3
1.6	Designing and developing a revised version of the file of the presentation	1.6 **Rubrics _1**	4
1.7	Improved delivery of the revised presentation in class. Review and discussion	1.7	4
2	**Portal web site "IT for first-year students of Mathematics at FMI, Plovdiv University"**		
2.1	Developing the first version of the web site	2.1	5
2.2	Peer evaluation and discussion of the fulfillment of assignment 2.1; negotiating criteria for the revised version	2.2	6
2.3	Developing a personal design of the template for the web site	2.3	6
2.4	Developing a revised version of the web site	2.4 **Rubrics _2**	7
2.5	Review and discussion of the revised web sites	1.7	8
3	**IT job profile**	3 List 2	8
4	**Using online glossaries Glossary**	4	8
5	**Online test preparation .: 1 2 3 4 5 6 7 8 :.**	5	9
	Final test & evaluation		10

For a start, the teacher should use a dedicated web site with at least four main purposes in mind:
1) enhanced communication with the students, e.g. announcements, assessment details, etc.;
2) course organization, e.g. lists, guidelines to assignments, feedback forms, course evaluation forms
3) online activities, e.g. mock tests, rubrics, glossary, training modules in communications skills, e.g. multimedia presentations, web site design, etc.
4) exhibit of students' deliverables, containing samples or, even better, complete projects by some or, hopefully, by all students, which serves as progress indicator, allows transparency concerning each student's performance and its evaluation, and is a source of competitive spirit.
More details on the didactic purposes of such dedicated web sites, as well as some examples, are available in [5]. CMS-based websites save a lot of teacher time and effort and greatly facilitate the web site update in terms of content, and, possibly, design.
Communication among students and teacher takes place mainly along four channels: dedicated web site, e-mail, instant messaging, and face-to-face contacts. Projects are submitted by email following agreed conventions concerning the file names, file formats, etc.
The process begins by communicating the goals and objectives from the project-based learning, which ideally should be elicited from the students. Then the project topics are negotiated, as students should come up with their own fields of interest. The teacher can access the dedicated website in authoring mode and, using an Internet connected computer and an LCD projector, can enter in real-time the topics and student names or academic numbers, as appropriate, next to each topic. The role of the teacher is to encourage students to make decisions and take responsibility, while assisting with technical matters, such as wording, arrangement, etc. Depending on their scope, projects are meant to be performed either individually or in small teams of two or maximum three students. We shall illustrate this with our list of IT-related topics, some of which are assigned as they are, while others are broken down into components. Alternatively, a teacher may decide to offer another domain for topics, e.g. mathematics in everyday life, fun with mathematics, etc.

Introduction to IT:

- The information age;

Hardware:

- Computer systems in a nutshell
- Input devices: keyboard, mouse, trackball, touchpad, joystick, light pen, graphics tablets, game controller, bar code reader, scanner, capture card, digital camera, digital camcorder, microphone, etc.
- Output devices: displays, printers, etc.

- Storage devices: magnetic, optical, and flash
- Computer ergonomics
- Assistive computer technology
- Buying a new computer / upgrading an old computer

Software:

- Operating systems
- Word processing and desktop publishing
- Spreadsheets
- Databases
- Computer graphics and design
- Multimedia
- Video games
- Programming and computer languages
- Computer networks: LAN, WAN,
- The Internet: WWW, e-mail, instant messaging, security, etc.
- Web site design and development
- Telecommunication: digital TV, digital radio, mobile phones, etc.
- New developments in IT
- IT jobs

Authoring tools:

- Editors: image, audio, video, web site
- Presentation software
- Project management software

As students take on the responsibility to do desktop research, consult peers, parents or friends, etc., while working on an assignment, it is the teacher's role to act as a project manager and subtly organize the whole process. If we took it for granted that students would diligently do all related activities entirely on their own and keep the momentum until the final week, we would be disappointed because more often than not they would lose enthusiasm and even control with the growing responsibilities they face with every new week. This is where the dedicated web site and e-mail communication come into play. Reminders can be in the form of feedback appreciating students' performance on a previous assignment, etc. Without facilitation, students would generally fail to comply with deadlines or fail to deliver at all and hence their motivation would greatly suffer. This is especially valid for academic contexts where attendance is not required by the institution.

Part of the facilitation involves detailed guidelines for each of the tasks. In our case, they are available on http://fmi.shotlekov.net/2.htm (User: fmi Pwd: fmi).

A key concept in this framework is that each student is personally involved as a 1.) "key speaker" on one topic through all stages in the presentation and web development projects; 2.) peer evaluator on the other topics; 3.) active learner as part of the audience who asks questions, takes notes, reflects, etc.

Another key concept is the "second chance" all students are invited to perform better based on further knowledge and counseling as a collaborative process in class and additional related activities, e.g. 1.3, 1.4, and 2.3 (cf. Table 1). Last, but not least, all activities are time-bound, i.e. there are deadlines for each of them. Efforts to comply with deadlines will pay off later both during the study, and during the work experience students will be involved in the future. The rubrics supplement the guidelines and are negotiated with the active involvement of all students with the informed facilitation by the teacher, which entails more input from the teacher who should have designed and developed model rubrics either as "Plan B" or to help with the verbalization of students' ideas.

As activities 1 and 2 are largely self-explanatory, we shall briefly comment on task 3 – job profile (cf. Table 1). This activity is meant to raise student's awareness of their prospective careers and thus increase their motivation. The guidelines for this task, which should be negotiated between students and teacher, involve job description, potential employers, personal attitude to the job, etc. In our case, it was just IT professions, but alternatively, teachers and students may decide on Mathematics-related jobs – this is why we provide a list in the second column. Ideally, these lists should be negotiated, as entries are generated by students and entered in the relevant section of the dedicated website in real-time using an Internet-connected computer and an LCD projector. Needless to say that there should be a name or academic ID number next to each topic, IT or Mathematics-related, as the case may be.

TABLE 2. Project based learning framework: job list

IT related jobs	Math related jobs
Applications developer	Actuary
Data analyst	Algorithm Engineer
Data communications analyst	Algorithm Specialist
Database administrator	Algorithms software engineer
Documentation Specialist	Analyst
Geographical information systems manager	Applied Mathematician
Hardware engineer	Applied Mathematician
HelpDesk operator	Applied Research Mathematician
Information security analyst	Automated Test Script Developer/C#
IT consultant	Budget Analyst
IT Infrastructure Manager	Computational Mathematical Programmer
IT project manager	Computational Mathematician
IT Team leader	Financial Manager
IT trainer	Financial Mathematician
Multimedia programmer	Market and Financial Analysts

Network engineer	Mathematical Technician
Network engineer	Mathematician
Office manager	Mathematics Instructor
Operating system designer/engineer	Operations Research Analyst
Software architect	Quantitative Research Analyst
Software engineer	Research Analyst
Software performance analyst	Research Mathematician
Software quality assurance specialist	Statistician
Systems administrator	Supervisory Mathematician
Systems analyst	Systems Engineer/Manager
Systems designer	Teacher of Mathematics
Systems developer	
Systems tester	
Technical consultant	
Web designer	

The use of online glossaries is proposed in order to build reference handling skills. In our case, we even compiled an online glossary related exactly to the project topics, but also encouraged students to identify other sources available online.
The dedicated website can host teacher and student-developed online activities. In our case, we offer activities we have designed to communicate the rubrics rationale by using authentic illustrations of the different aspects of effective presentations or good practice in web development. In addition, we offer eight mock tests –Activity 5 – in the framework meant to prepare students for the final exam both in terms of scope, and in format. Other online activities we offer are course evaluation and feedback. Thus, students have the opportunity to apply critical thinking skills, reinforce the feeling that their opinion matters, and possibly make steps to a prospective action plan to further improve their current knowledge and skills. Last, but not least, there can be a test authoring facility to help the teacher produce an online final test, e.g. [6].
Assessment and evaluation policy can be left to the teacher's discretion, but should be agreed and clearly communicated to the students from the very beginning. Each activity should bring the student a mark, while the final grade is a weighted average of the marks on the projects (e.g. 60%) and the final test mark (e.g. 40%). In cases of required attendance, the ratio could be 60-30-10, for instance.

Project management skills are beneficial not only to the teacher, but also to students, both in academic and work contexts. That is why we have dedicated the second part of the framework to this key competence. As it is considered in detail in [7], we shall very briefly mention only a couple of points. The underlying idea is that the teacher uses project management tools and techniques to involve their students in a learning process in which they will apply existing and acquire new knowledge about IT (or Mathematics pending to the students-teacher agreement)

playing the role of project team members or team leaders. According to the PMBOK Guide, project management processes can be attributed to five groups: "initiating; planning; executing; controlling, and closing [8]. The teacher and students can follow these domains during a course of the type assumed here, i.e. for first-year students of Mathematics.

TABLE 3. Project based learning framework: module 2

#	ASSIGNMENT	Guidelines	Week
	MODULE II (e.g. Trimester B, or Elective 2)		
	Educational project management		
1	*PM essentials: training*	1	1
2	*PM essentials: student input*	2	2
3	*SWOT analysis*	3	3
4	*Team building*	4	3
5	*Project ideas*	5	3
6	*Baseline study*	6	4
7	*Stakeholder analysis grid*	7	4
8	*Key risks & assumptions Grid*	8	5
9	*Monitoring & evaluation Plan*	9	5
10	*WBS*	10	6
11	*Schedule*	11	6
12	*Gantt charts*	12	7
13	*CPA charts*	13	7
14	*Responsibility matrix*	14	7
15	*Budget*	15	7
16	*Project proposal*	16	8
17	*Prepare a presentation*	17	8
18	*Deliver a presentation*	18	9
19	*Donors meeting/ Project proposals evaluation*	19	9
20	FINAL TEST & Course evaluation		10
	KEY: PM – Project Management; **SWOT** – Strengths, Weaknesses, Opportunities, Threats; **WBS** – Work Breakdown Structure; **CPA** – Critical Path Analysis		

The schedule is tentative and can be adapted to comply with the actual context. The same flexibility holds for the content. On our pilot course, the students decided to develop project proposals related to studying IT at FMI. After they joined different teams based on the SWOT analysis and other team building activities, the five teams, made up of between three and five members, came up with these project ideas:

1. Online Career Center;
2. Online Notification Service;
3. Easy Course Sign-up;
4. Electronic Library for Academic Education of IT Students in University of Plovdiv „Paisiy Hilendarski";
5. Online Testing, Grading and Evaluation.

Again the role of the teacher is that of a facilitator who assists students in verbalizing their ideas, rather than offering pre-set ones.

In other contexts, the students of Mathematics could come up with other project ideas, e.g. "Teaching fractals in the primary school: lesson plan and unit development", "Mathematics: examples from technology: five-hour course for secondary school students", "Think with your hands to study Math – hands-on activities for secondary school students", etc.

Once the teams have agreed on the project ideas, they can proceed towards drafting the project implementation plan. In order to go all the way from brainstorming the ideas to the project proposals and their PowerPoint presentations during a mock donors meeting, the students on our pilot course built on their existing knowledge of IT while acquiring new knowledge as needed for the purposes of their teams' projects. In addition, they learned the basics of project management themselves which was demonstrated in their project proposals, as all 5 were approved by the simulated "donors meeting".

Both the teacher and the students share the same tool box: project management techniques. While the students apply them to their own project on their team, the teacher employs these to manage the course as a whole. Thus, they are really very much in the same boat.

IV. CONCLUSION

The piloting of the framework for project-based training at FMI showed that this approach allows students to reflect on the educational process they are involved in, which results in learning from mistakes and missed opportunities, in higher motivation resulting from minor or major achievements at different steps of the framework, in more degrees of learner autonomy, to name a few. Students enjoyed the experience and found it an empowering one which had an added value in terms of incentives to go into more depth with their studies. Students of mathematics would definitely feel better prepared and more aware to pursue careers outside the strict field of pure mathematics where they would need extra knowledge and skills.

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