Innovative Approaches for Teaching BPS: First Implementations of Business Game-Like Activities

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Abstract

Experiential Learning (ExL) has long been considered a useful and necessary tool in educational courses in several different fields, including engineering. Nevertheless, traditional didactical approaches have prevailed, in particular, in Bachelor and Master Engineering programs, at least in Italy.

This implies the focus is kept more on theoretical aspects even for disciplines in which practical activities and learning by doing could provide the necessary competence for students to enter the job market promptly. Futhermore, ExL is recognized as providing a more immersive educational environment, capable of increasing participation and motivation in students.

One of the techniques introduced by the ExL consists of roleplaygames, some of which in the form of business games. This work reports about the main outcomes from an initial implementation of a business game-like approach to train perspective building envelope and energy systems designers. In particular, the game is intended to train students in the use of building simulation, showing what the potential and the peculiarities of the job can be when approaching the market. In addition, since it is commonly recognized that, while BPS is widely used in teaching and research, it is not widespread among practitioners, the game was also conceived to promote BPS use in practice.

The main features, including constraints and critical points, of the implementations within a university course in an Energy Engineering study program are described together with some suggestions for future improvements.

1. Introduction

Experiential Learning (ExL) is commonly defined as a teaching approach based on learning from experience, as opposed to a more traditional and formal education, which is mostly focused on the presentation of somehow abstract concepts by the teacher. Indeed, the relevant difference does not refer to the abstraction, rather than to the approach, which requires the learner to assume an active role in the learning process.

Even if it is indisputable that ExL can contribute to filling the gap between theoretical knowledge and practical skills and competences that is so often observed in many higher educational programs, the focus is more on the process of creating and acquiring knowledge.

Nevertheless, the experience itself, which is often included in many study programs at least in the form of traineeships and internships, is not enough. As introduced through the foundational theories of experiential learning by Dewey, Freire, James, Lewin, and Rogers, a transformation of the experience is required.

In the Experiential Learning Theory, introduced by Kolb and Kolb (2009, 2017), two dialectically related modes of grasping experience—Concrete Experience (CE) and Abstract Conceptualization (AC)— as well as two dialectically related modes of transforming experience—Reflective Observation (RO) and Active Experimentation (AE) - are combined in a cyclic and iterative process.

In this respect, the theoretical concepts provided by the teacher in the traditional model are still required to support knowledge development, even if it emerges more and more from an interactive relation between teacher and learners, and between reflection and experience.

This also leads to some extent to a larger engagement of the learner. In addition, due to the constructivist nature of the learning process, learning outcomes are the result of a personal interpretation by the learner.

Finally, this is compatible with a more recursive interaction between theory and practice, and compatible with a process of gradual development

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of knowledge, in which foundational concepts are not necessarily provided prior to the practical experimentation.

It seems there is a general consensus towards the broad effectiveness of ExL in achieving all learning outcomes, namely knowledge, skills and competences (or responsibility/autonomy, according to the definition of the European Qualification Network). In educational areas and levels, such as Bachelor and Master Engineering programs, where it is important the student be trained to not only to acquire theoretical skills but also to take a more practical attitude towards problem solving, design, decision making, etc., this appears of crucial importance.

However, in many cases, only some of the tools proposed by the ExL are implemented. As an example, Baker et al. (2012) confirm that, despite the robust use of experiential learning in fields such as agricultural education, "experiential learning" and "experiential education" have mainly been used to describe teaching approaches such as field work experiences, internships, outdoor education, adventure education, vocational education, lab work, simulations, and games (Itin, 1999).

In this framework, the implementation of ExL concepts in courses dealing with Building Physics and Building Performance Simulation is described as necessary by Beausoleil-Morrison et al. (2015), to "develop the necessary knowledge and skills to effectively apply BPS tools", to the point that "this must be recognized in the way we teach the discipline".

The above reasons led to the adoption of ExL practices within a course in Building Physics and Building Energy Simulation in a Master program in Energy Engineering at the Free University of Bolzano (Gasparella, 2017). Not only was BPS awareness and competence improved through the implementation of numerical solutions to the theoretical governing equations, but the learning of the theoretical foundations of BP itself was enhanced by the development of the solution approaches with the use of a spreadsheet, instead of working with already available simulation tools. This allowed combining experientially the application of the concepts with introducing the students to the use and understanding of BPS. The students were also asked to apply BPS in small groups and develop a project to be presented and discussed at the final exam.

Although BPS is a powerful tool for designing, operating, and renovating buildings, its use in professional design practice seems to be less common than expected and to lack professionals able to work with it, independently of the efforts put into simplifying interfaces and integrating functionalities within the most common design tools (Soebarto et al., 2015).

With the additional goal of increasing the awareness and readiness of graduates to use BPS tools once entering the job market, it made sense to extend and rationalize the use of ExL techniques, turning the project work into a business game, or at least to start moving in that direction.

Business simulation games are roleplay games introduced in the 1950s to train students in business schools. As reported by Jackson (1959), they derived from the war games used in Germany in mid-19th century and later in Japan, in preparation for World War II. Business games are generally based on strategic decisions that imply some consequences for the players, providing direct feedback for their decisions and actions. In addition, detailed rules and realistic complexity are required to mirror real applicative contexts. Competition among teams is often included to engage participants and improve interactions within the groups. Specialized games can focus only on some areas of business management. Faria (1990) reported a rapid spread of the tools in the US in the thirty years from 1960 and 1990, even if a wide expansion potential was still present.

The use of business game-like tools in the field of BP and BPS, as in other engineering and technical areas is not well documented.

IBPSA, the International Building Performance Simulation Association, has introduced a Student Modeling Competition taking place within the biennial Building Simulation conference, since 2013. So far, five competitions have taken place (namely in 2013, 2015, 2017, 2019 and 2021). In the 2013 edition, the students were asked to use simulation to design an energy-positive house, limiting only the building geometry and focusing on energy, under constraints on comfort and IAQ. In 2015, the focus was on an office building, and on designing and testing a mixed-mode ventilation strategy. In 2019, a more structured case was proposed, considering an existing historical building, with peculiar constraints limiting the possible interventions, and asking the students to undergo a 5-step approach (simulation pentathlon) from simulating the existing building to optimize the overall building performance (including multi-objective optimization). The 2021 edition focused on low-tech buildings and on the use of simulation to improve comfort, while preserving the energy efficiency.

In this work, a preliminary report is presented on the attempt to implement a business game-like task in the above-mentioned course in Building Physics and Building Energy Simulation in the Master program in Energy Engineering at the Free University of Bolzano. The existing project work was reorganized and proposed in the form of a game, with small groups competing and comparing their solutions in public presentations during the course.

The game focused on the renovation of a residential building. It was organized into four phases, asking the students to refine the project through the introduction of additional and contrasting objectives, and building on top of the results of a preliminary evaluation of the baseline configuration.

The activity required the students to use a BPS tool, with only basic preliminary knowledge, while theoretical foundations related to BP and to the numerical solutions of the governing equations were provided in parallel, considering further applications of the ExL approach, as described in Gasparella (2017).

2. Methods

2.1 Experiential Learning Experiences

An ExL integrated teaching method for a course dealing with Building Physics and Building Performance Simulation within a Master program in Energy Engineering had been under development and testing for ten years at the time of writing this paper. In approximately 90 hours, the fundamentals of building physics and modeling are presented, together with the main aspects of thermal comfort and indoor air quality. The course starts illustrating the thermodynamic balance of the indoor air volume, according to the model called “air node balance”.

The definition of the boundary conditions for solving the balance requires characterizing the unsteady thermal conduction in the envelope components, which in turn can be determined only through the surface balances, so through the analysis of convection, long and short wave radiation interactions at the external and internal surfaces for opaque and transparent envelope elements, and so on.

For each of the mentioned processes (i.e., conduction, convection, radiation), the main controlling equations are defined and their numerical or analytical solutions discussed, to end with a step-by-step implementation of a detailed model in a general productivity spreadsheet environment. As a result, at the end of the course, the students are able to develop a comprehensive simulation tool that, despite the limitations in the computational efficiency proper of a spreadsheet, can compare favorably to the most widespread tools available on the market in terms of both detail and accuracy.

In short, the student has the opportunity of applying the theoretical foundations, experiencing through simulation the behavior and relevance of each different process, and its contribution to the overall performance, observing the outcomes, conceptualizing the findings and actively interacting with the experimental environment, while understanding the inner operation of BPS tools.

The learning circle encompassing the four phases of Concrete Experience (CE), Reflective Observation (RO), Abstract conceptualization (AC), Active experimentation (AE) is therefore entirely implemented and repeated iteratively while progressing with the analysis of the different aspects.

2.2 Towards a Business Game

A business game is a roleplay game in which the player/learner has to perform tasks and obtain results/feedback typical in professional practice, generally in the managerial field. In particular, the learner is expected to apply knowledge, skills and capabilities to evaluate alternatives and make decisions.

In the case of graduate students in Energy Engineering with a focus on Building Physics and Building Energy Systems, it is likely that in their professional activities they have to contribute to or directly perform the design of buildings, analyzing energy-related aspects, optimizing investment, and maximizing comfort conditions. They are expected to deploy the skills and competences necessary to (i) simulate performance, (ii) verify reliability of results, (iii) analyze outcomes and evaluate their sensitivity to the design parameters, (iv) optimize contrasting objectives, (v) make sensible proposals and find trade-offs, (vi) present and discuss with clients or other consultants, (vii) manage time and resources devoted to the analysis, understanding costs and benefits, in the different design phases.

To this aim, the project originally included in the exam assignments has been redesigned to serve as a sort of roleplay game.

The students had to start working on an assigned project in small teams of 3-4 persons, as if they were a design studio in charge of renovating an existing residential building and giving advice to a client. Students in a team could have different roles but also discuss ideas and methods.

A simulation tool was shortly introduced during the first weeks of the course and students got familiar with it through a guided example presented by some teaching assistants, who had been former students in the same course.

One of a couple of different buildings (Fig. 1) were randomly assigned to each of the nine teams.

Both buildings were detached houses, with two storeys for a three-person family. The envelope was typical of the ’60s, therefore lacking any insulation and adopting single pane glazing. The buildings had different internal layouts, different orientations (main axis East to West or North to South), and different locations (Bolzano, Italy – cold winter and warm to hot summer, or Graz, Austria – with colder winter and slightly milder summer as in Fig. 2).

Shade cast from nearby buildings is also included in the evaluation in order to promote careful analysis of the context.

Even if non-thermal energy performances were not considered, students were encouraged to maximise daylight as a preference from the owner. While guaranteeing minimum access to daylight through the prescription of a minimum WWR was requested, increasing window size, changing their position and redefining the internal layout was allowed.

Students were asked to proceed to the following steps:

(i) Analysis of the baseline case,
(ii) Assessment of the energy impact of intervention measures,
(iii) Definition of cost-effective solutions, and
(iv) Assessment and improvement of thermal comfort and indoor air quality.

Data to perform the economic analysis (costs for the different interventions, including windows resizing and repositioning, layout redesign and shades installation) were provided after phase (ii). Input and requisites for the comfort analysis were provided after the cost-effective optimization in phase (iii).

At the end of phases (ii), (iii) and (iv), the teams were asked to give a short presentation (10-15 minutes) to the other groups (three times in total), receiving comments and answering questions. This represented a novelty compared with the original project work, which was mainly discussed at the end of the course and only with the examiner.

In two rounds after the second and third presentations, all teams were also asked to evaluate each other’s work, selecting the best one for each of four categories (i) presentation; (ii) innovation; (iii) comprehensiveness; (iv) performance. From the preferences expressed in the two rounds, a ranking list was formed for each of the evaluation categories, and updated with the teacher and teaching assistants’ evaluations. Four teams were commended as the best in one of the categories and one as overall winner for the game.

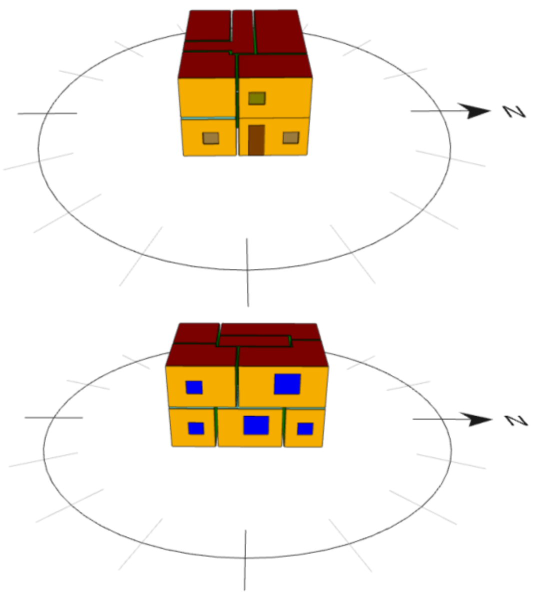

Fig. 1 – Residential buildings for the business game. The cases of Bolzano (above) and Graz (below)

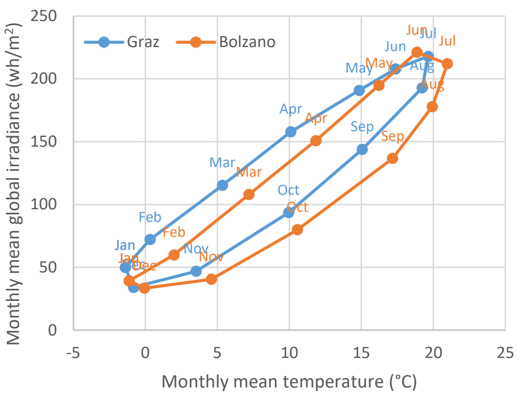

Fig. 2 – Reference climatic conditions (air temperature and global irradiance on the horizontal) in Bolzano and Graz

3. Results and Discussion

As for the outcomes of the adoption of the game, an initial evaluation concerns the students' behavior and strategies. In particular, some interesting techniques were observed among those implemented to overcome limitations in the calculation capabilities and minimize the required efforts.

Most of the groups developed a customized approach to assessing the combined effect of different intervention measures and to adding optimization objectives in an efficient way.

Some of noticeable strategies adopted in the different phases are reported below:

(i) The preliminary analysis of the baseline configuration was generally conducted through a multi-zone simulation. One of the teams, however, ran free-floating simulations considering individual rooms, to point out specific critical points from peculiar temperature profiles. Some teams also included daylight evaluation, even if not explicitly requested.

(ii) Most of the teams decided to redefine the layout and window position, to optimize both the distribution of spaces and the access to solar gains and daylight. In many cases, preliminary parametric evaluations were performed with different window sizes.

(iii) Some teams minimized the cost of a full sensitivity analysis on each of the intervention measures, establishing a preference order. They selected the most influential interventions, adopting parametrically the most extreme levels allowed for each. They then kept the order in the optimization steps. Some others increased the level of each intervention at a time (such as the insulation thickness), stopping when the marginal improvement was reduced to below a certain percentage, and moving to the next with the same approach.

(iv) Energy optimization followed generally from either the simple combination of the preferred levels of the different intervention measures, or a sequential approach. That foresaw the optimization of the most impacting intervention, adding on top of it the second best, and so on. In some cases, students seemed more aware of the possible non-linear interaction effects, so solutions related to the previous intervention level were explored again after adopting the new one.

(v) Cost optimization was mostly based on the evaluation of the economic performance (simple payback period) of the energy optimized configurations. Subsequently a reduction in the investment cost and so in the payback was attempted through the decrease or removal of some of the interventions, such as of the reduction of the insulation thickness or moving back to single or double pane glazing from double or triple, respectively. Some groups decided to cap the economic indicators.

(vi) Comfort (thermal and IAQ) was generally only assessed verifying the compatibility of the renovated configuration(s) with the prescribed comfort category. In some cases, when overheating issues were highlighted, some control strategies dealing with increased natural ventilation or with some refined assumptions about the occupant's behavior and presence were considered. Somewhat surprisingly, some of the teams simply decided to adopt air conditioning.

Presentations deserve a special mention. Presentations proved to be a good tool not only to engage the participation and practice some soft skills, such as communication strategies, but also to self-assess the quality of the work. Reiteration led to an increased quality level: some groups were motivated to increase the number of simulations, explore different solutions, use different approaches, and in general to verify their own results, and refine the presentation strategy. Overall, presenting and discussing among peers and with the support of the teacher and assistants proved to be effective in reinforcing, together with the game itself, the effectiveness of the different steps in the learning cycle, and improving the overall outcomes of the course.

Some general pros and cons can be listed as follows. As concerns the positive aspects:

(i) A simulation tool was learned through its direct use, with little need for training but some hours to develop a guided test case together with the students;

(ii) A more competitive context and an early start was able to increase collaboration and team working within groups with respect to the original project work. Some level of specialization of the members of a group was observed;

(iii) The business game promoted a more practical mind-set, more aware of real-life limitations and more sensitive to a client's perspective, forcing students to consider aspects they would not be fully aware of otherwise;

(iv) Multi-objective optimization without the availability of optimization tools, which could have been considered detrimental, turned out to be quite beneficial. It forced the students to develop empirical approaches to assess sensitivity and refine solutions;

(v) Public discussion and multi-step development allowed the comparison of the intermediate achievements of the groups, stimulating students to improve their approaches and recognize the limitations of the proposals.

Some negative outcomes or aspects to improve on have that have been identified are:

(i) The game had to start even earlier than the theoretical lessons to be able to provide adequate insight into the involved phenomena. That is accepted in ExL but would require deepening the phase of abstract conceptualization and the support for the teams and students;

(ii) Some of knowledge and skills required to develop the project are partially missing, such as those related with the economic evaluation. This could require in the future a multi-disciplinary approach in which the business game encompasses different courses;

(iii) A significant amount of time had to be allocated during the course, in particular for autonomous work, which might lead to compression of some parts and overloading of the students;

(iv) MOO without reliance on optimization tools led to sub-optimal solutions and possibly to inconsistencies between the findings of different groups;

(v) The structure of the business game still needs to be refined, and some dynamics and roles/ responsibilities introduced more clearly.

(vi) The evaluation grid needs to be improved to support the conceptualization phase and generate more competition among groups.

4. Conclusion

This work reports on the implementation of a business game-like task in a university course in Building Physics and Building Energy Simulation for a Master program in Energy Engineering at the Free University of Bolzano. The course had already been designed and organized to take advantage of some ExL techniques. In particular, BP and BES concepts and competences were already developed in a learning cycle approach, implementing and experimenting on the theoretical foundations presented in class through the development of a simulation spreadsheet including all the relevant aspects contributing to the building dynamic energy behaviour.

In this framework, a project work was designed in the form of a business game, with small groups competing and comparing the solutions proposed in a series of presentations to the class. The game focused on the renovation of a small residential building. It was organized into four phases, asking the students to refine the project by adding progressively contrasting objectives, such as energy, costs, and comfort.

The activity required the students to use a BPS tool, with only basic preliminary knowledge, while theoretical foundations related to BP and to the numerical solutions of the governing equations were still being provided in parallel, as described in Gasparella (2017).

Overall, the attempt improved the quality of the experiential learning approach proposed in the course, stimulating greater participation and promoting a deeper awareness of the main concepts, skills and competences required in the field. The business game represented a step forward regarding the usual project work, in particular because of its structured approach, the focus on a couple of reference cases only, the presentations and interactions occurring after each phase and the discussion within and among the groups.

There is still a significant amount of work to do in order to:

(i) Provide more structured rules and roles, to make the game more realistic and engaging.
(ii) Consolidate the features of the case studies in order to facilitate the development of some parts which would have needed more information and to simplify the verification.
(iii) Involve professionals in the definition of the case study (to make them more realistic as from point i) and possibly also in the discussion and evaluation of the results
(iv) Extend the game to other universities and introduce "finals" levels involving the best groups from each university

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