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classEx – an Online Software for Classroom Experiments

Marcus Giamattei und Johann Graf Lambsdorff

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classEx - an online software for classroom experiments

Marcus Giamattei[a,1,*], Johann Graf Lambsdorff[a,2]

[a]*Innstrasse 27, D-94032 Passau. Phone: 0049 851 509 2550*

Abstract

classEx is a novel software that allows lecturers to carry out experiments in the classroom with an instantaneous graphical illustration of findings. Standard experiments with multiple treatments, monetary incentives, roles, groups, rounds and stages are available in a ready-made format. A back end allows more sophisticated users to implement their own experiments. We present examples, describe the architecture and show how the design can be tailored to become useful for research.

JEL Classification: C9

Keywords: Experimental Software, Classroom Experiments, Student Activation, Ex-Post Screening, Double-Blindness

1. Introduction

Up to date, a variety of experimental software has been programmed, largely targeted towards usage in the laboratory. This kind of software aims at generating data for research, providing experimenters with full control of the environment and an increasing variety of tools to design an experiment according to their needs (Fischbacher, 2007). Little has been done to provide lecturers and researchers with experimental software to be used in the classroom. There are at least two reasons why such software can be useful.

First, lecturers at many universities are increasingly employing interactive tools. One example are Audience Response Systems (ARS), aimed at actively involving students (Stowell and Nelson, 2007; Kay and LeSage, 2009; Bachman and Bachman, 2011; Voelkel and Bennett, 2014) and increasing their participation (Caldwell, 2007). ARS help students replicate what they have learned. But requests have been raised that interaction in lectures should also support understanding, application and analysis (Dangel and Wang, 2008). Up to date, this has mostly been achieved by pen-and-paper experiments (Frank, 1997; Emerson and Taylor, 2004, 2010; Dickie, 2006; Durham et al., 2007). Bergstrom and Miller (2000) devote a whole book to teaching microeconomics by help of interactive games. But pen-and-paper is a time consuming approach, which lacks opportunities for immediate feedback. This shortage can be overcome if students use their mobile devices, such as smartphones and netbooks. Such applications for smartphones remain scarce, one exception being Ball et al. (2006). classEx aims at overcoming this shortage.

Second, the classroom has sometimes been discredited as a useful environment for carrying out experimental research. Levitt and List (2007, 165) argue that early experiments

*Corresponding author.

Email addresses: marcus.giamattei@uni-passau.de (Marcus Giamattei), jlambsd@uni-passau.de (Johann Graf Lambsdorff)

[1]Research Assistant at the University of Passau, Germany.

[2]Chair in Economic Theory at the University of Passau, Germany.

simply involved punctual college sophomores that are interested in the research and thus readily cooperating with the experimenter. Classrooms provide easy access to participants at low costs, but appeared inferior in a variety of areas such as randomizing treatments, avoiding collusion, preserving double blindness and incentivizing students in a good way. On the other hand, experiments in the classroom have been restricted to pen-and-paper methods, which are mostly one-shot and limited to simple forms of strategic interaction. Games that require repetition and feedback are thus almost impossible to implement. As we will argue here, these shortcomings can largely be overcome by help of adequate software.

This study presents some examples on how to use classEx for teaching (section 2), describes the software architecture (section 3 and 4) and discusses how it can be employed for research (section 5).

2. Interactive Teaching with Experiments

classEx is a web-based server application, with which participants can take part in experiments and questionnaires via their notebooks and smartphones. The only requirements are a stable internet connection and a standard browser. The same holds true for the lecturer. The lecturer can use the presentation screen in the lecture hall to display the control panel and the results of an experiment. The following teaching scenarios explain the use of classEx with some simple experiments. While the first experiment also involves a description of the procedures for using classEx the latter only mention the game itself.

Figure 1 shows the typical lecturer screen after logging in. This screen is visible to the whole audience hall. The text on the top provides common information for all players and describes the game. The game is an implementation of a nudge (Thaler and Sunstein, 2008). In their book of the same title they describe how framing and defaults change peoples behavior. This simple experiment involves a decision for or against a retirement plan, which is described with an abundance of details. After explaining the game, the lecturer presses the start button (s. figure 1) and all participants can start the game immediately.

The screen of the participant can be seen in figure 2. One decision is marked as default when the student starts the game. The student can change the selection or keep the default. After sending the input a confirmation is displayed, including a waiting message. While participants make their choice, the lecturer is constantly updated on the number of participants who are logged in and on how many have already decided.

The clue of the experiment is that half the participants are provided with the pro-option marked as default, the others with the contra-option pre-marked. This resembles a classical

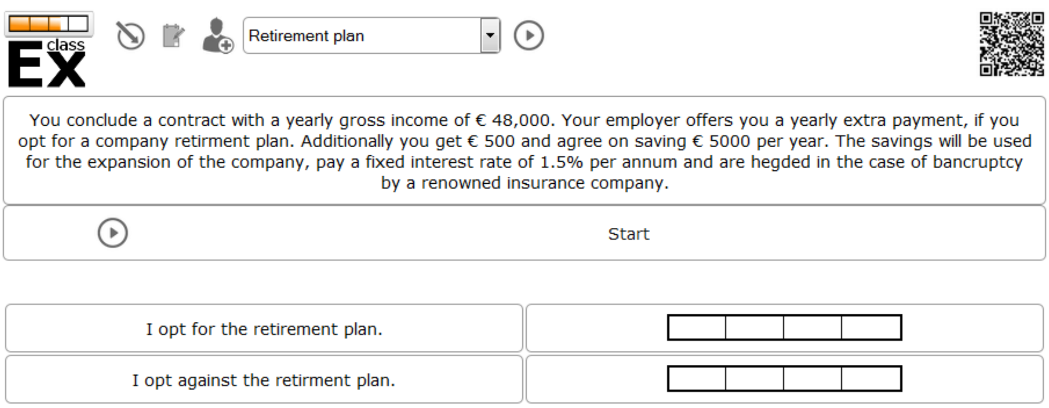

Figure 1: Lecture Screen at the Start of the Game

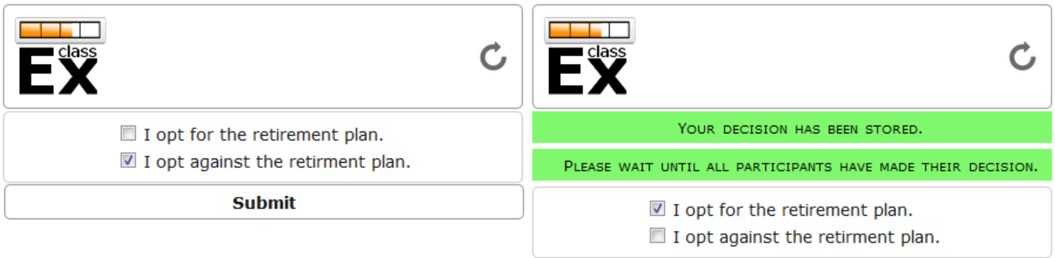

Figure 2: Participant Screen

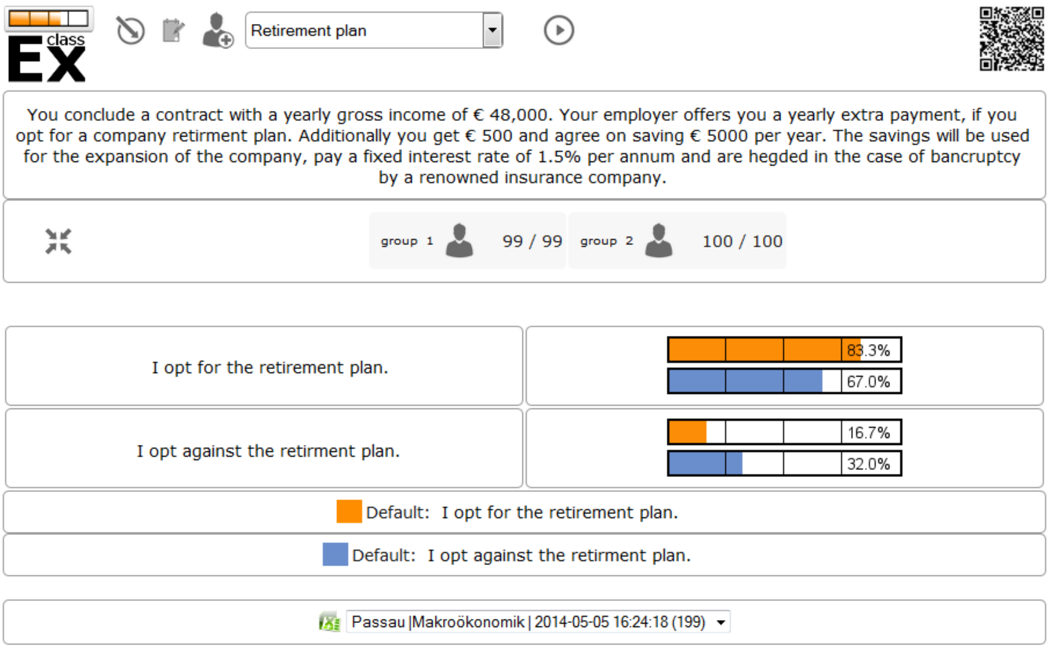

Figure 3: Lecture Screen at the End

between-subject treatment design with the use of private information. As soon as (almost) all participants have made their choice, the lecturer ends the game and the results are displayed immediately, as can be seen in figure 3. Participants are now informed about the existence of two treatments, allowing the lecturer to discuss the results.

As shown in figure 3, 199 students took part in a test run carried out on May 5th 2014, with 99 students in the first and 100 in the second treatment. The bias towards the default option is clearly visible. While only 16.7% opt against the retirement plan when the default is set to take the plan, this rises up to 32% with the second option as default. The lecturer can thus demonstrate and replicate an effect with the students own data, helping to improve credibility and providing students with a deeper sense of standard research results.

At the bottom of the page (s. figure 3) the lecturer can access results of other lectures or universities in which the experiment was played previously. This serves as an insurance against unexpected or implausible findings that may randomly arise. Lecturers are given the comfort that involving students interactively does not provide a risk to the didactic goals. Also, continuous decisions can be retrieved. A coordination game where participants decide

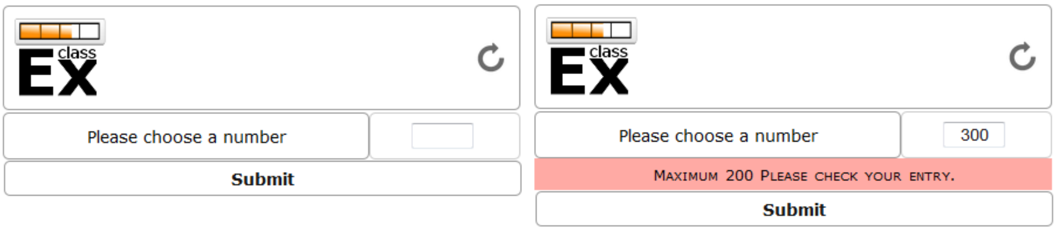

Figure 4: Participant Screen

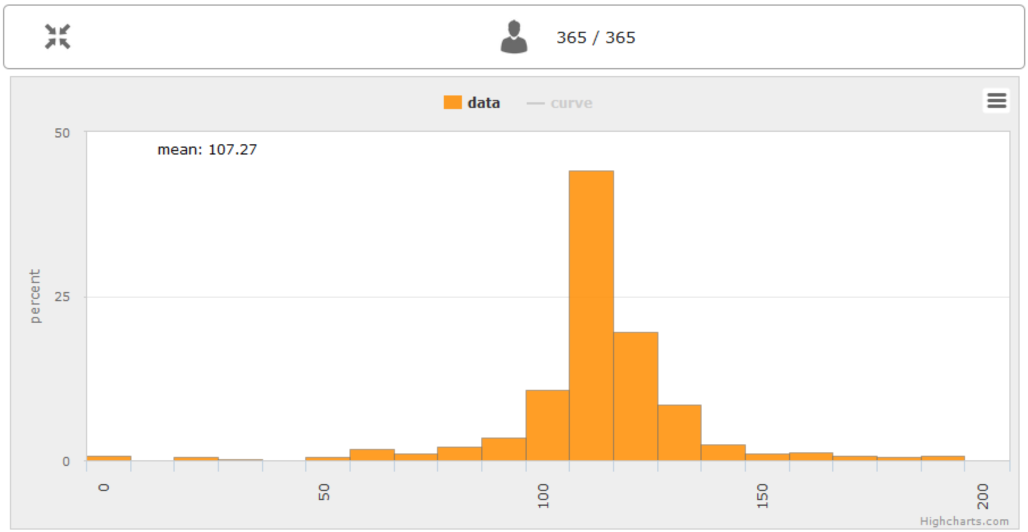

Figure 5: Beauty Contest Game

on a number between 0 and 200 can serve as an example. Here, the participant who gets closest to the mean earns 20 euros. This is referred to in the literature as a $p = 1$ beauty contest (Nagel, 1995). Figure 4 displays the input screen as well as the control, shown if a participant enters a number above a pre-specified maximum.

After all participants have made their decision, the lecturer closes the voting. Figure 5 displays the result screen for a session with 365 participants, with results obtained in a second round of the game. Lecturers can utilize the results to demonstrate the history dependence of human behavior. While any number can be the equilibrium in this game, the average chosen by all participants reveals a remarkable persistence across rounds. Averages from the previous round serve as focal points for current decisions.

This example also demonstrates another important feature of classEx. With the help of tokens, real payoffs can be paid out to participants. Participants get an individual winning code displayed on their smartphone if they were selected as winners. With this code, they can be disbursed by the lecturer or by a third person. A third example involves the implementation of different roles and interaction in pairs. Each participant in the lecture hall is matched with another player, one being the red and one the green player. Let us illustrate this with an assurance game. Figure 6 displays the lecturers screen and the payoff matrix of the game. If both players invest, they reach the highest payoff. But if only one player invests while the other does not, the investors payoff is reduced to 0. In addition to the matching in pairs of two, these pairs were assigned to different treatments.

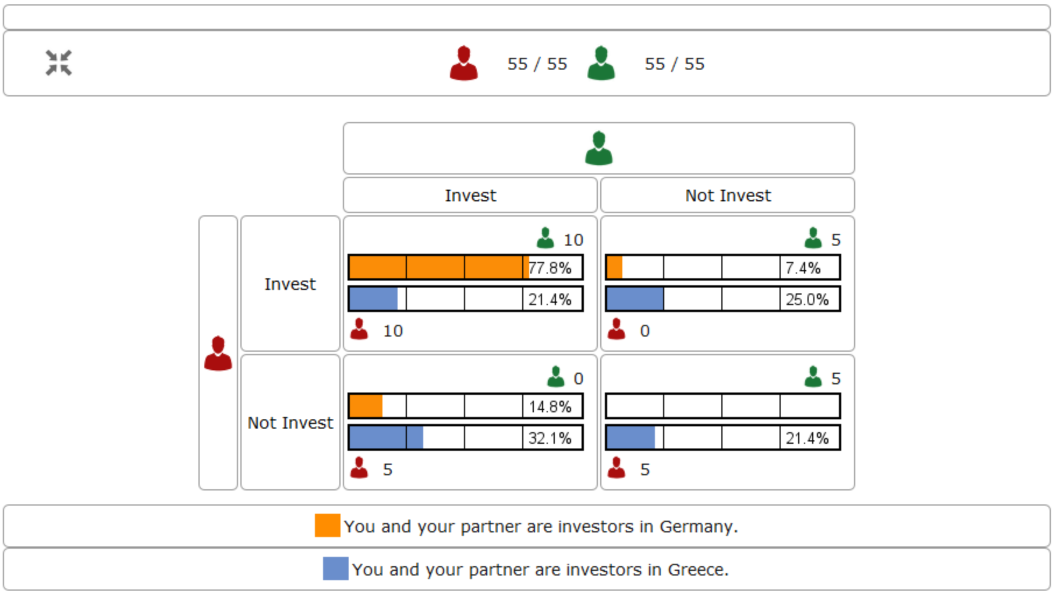

Figure 6: A Coordination Game

Half of the pairs were given the frame that both of them are investors in Germany, while the other half received the frame that they are investors in Greece. As can be seen above, 77.8% of participants coordinated on joint investment in Germany but only 21.4% did so in Greece. Hence, the framing affected behavior. This experiment was used in a macroeconomic lecture to demonstrate how perceptions of the environment may influence investment decisions. Behavior can be incentivized, as was done in the session, by randomly drawing one pair of players and paying their payoffs out in euros. While these examples only provide a first insight into the possibilities, many other experiments are possible. Experiments can be configured and designed according to a lecturers needs and ideas. A wide range of experiments have already been implemented and are open to replication. Beside pure experiments, this also involves questionnaires like e.g. simple multiple or single choice questions or Likert scale based constructs. Standard games like public good, ultimatum or trust games are available. Adjustments to each of these games can be made according to the lecturers preferences, for example the framing of the task, the number of randomly drawn players to receive a payoff or the number of rounds to be played.

In addition to such ready-made experiments, lecturers can design their own. The design and architecture are described in the following sections.

3. Software Design

The software classEx is web based and builds on standard client-server architecture. It is available free of charge to any lecturer and any user. In the following, the main architectural features will be explained in order to show how classEx integrates experimental design issues with up-to-date approaches in software development.

Standard well-known formats. The software is implemented entirely in PHP, HTML and Javascript and data are stored in a MySQL database. Therefore, classEx relies completely on open standard web formats which are well documented and known to a broad range of users. It is not necessary to learn a completely unfamiliar programming language. Learning to use classEx thus builds on knowledge that is useful also outside the context of conducting experiments, which increases the willingness to invest in learning how to setup experiments with classEx.

Centralized architecture. All data on games and their structure as well as all results are stored in a centralized structure and can be easily accessed by any client. This allows sharing and comparing experiments of different experimenters. Therefore, classEx is implemented as a centralized service and not distributed as downloadable software. Games can be categorized according to their game theoretic logic and organized in a systematic way. A data repository of previous results is made possible by the centralized architecture.

Light-weighted communication and user interface. One needs to pay attention to the volumes of transferred data because mobile networks are still subject to capacity constraints regarding the speed and the simultaneous access of large groups of participants. ClassEx tries to minimize this through a clear structure, a cache system, large computations done on the server and CSS3 Layout (see below). classEx incorporates the standard techniques to make mobile websites faster. Therefore, additional Javascript features are implemented so that some simple calculations can be done on the client-side to limit the number of necessary connections to the server. classEx relies on the standard web caching features to reduce the loading volume.

Bi-directional communication in classEx largely builds on AJAX Scripts in order to avoid reloading the page too often. For direct interaction in the classroom, AJAX automatic reload can also be turned off so that subjects reload when they are told to do so. Additionally, Javascript and AJAX are used to enrich user experience and to give instant feedback before submitting the decision.

Layout. classEx uses standard CSS3 technology for layout purposes. Especially the new design elements in CSS3 are light-weighted and flexible. classEx provides a fixed standard design with a range of basic design elements such as boxes or notification. The standardized layout ensures usability both on mobile and non-mobile devices. Especially for mobile devices and limited space on a mobile screen, classEx provides enlarged symbols and input facilities. Still, users can use the standard HTML format elements to integrate user-formatted text and incorporate links, tables or images.

Easy access. Another important issue is the fact that subjects can access experiments in a simple and fast way. classEx does not run as an application (which has to be installed beforehand) but only as a (mobile) website. Subjects open their browser and can immediately participate in the experiment. These low technical barriers assure easy access and therefore high participation rates. Installing software or an app before participation may deter subjects from taking part in the experiment, which would be problematic in particular when experiments are carried out with a more spontaneous, one-shot audience. Depending on lecturers preferences, the access may not be limited at all (in order to ease access further) or by a single session password which is identical for all subjects (in order to assure that only those attending the lecture participate). The ip address then serves as unique identifier.

Real monetary payoffs. In order to be able to hand out real payoffs, classEx provides a system of winning codes. Winners receive an automatically generated and unique winning code and can collect their payoffs by stating their winning code to the experimenter or a third person who distributes the payoffs. These winning codes allow no immediate tracing back to the actual person and are not linked in any way to the login information provided by the subject. Therefore they assure a standard level of anonymity while allowing for a method of linking participants choices to monetary incentives.

Flexible Game Structure. classEx supplies a data architecture, which provides a battery of ready-made standard experiments, but also a flexible structure that enables users to design games in line with individual needs. This architecture is explained in the following section.

4. Structure

classEx models games in order to assure simple access, flexibility and allow for varieties of different games. It builds on the following game structure, which is exemplified in figure 7 and explained below. For a more technical version of the architecture see the appendix.

Stages. Games consist of several stages. There are at least 2 stages, one for the decision input and one for the result output. Stages are ordered sequentially and are meant to be synchronization points in the game. Synchronization means that for the next stage to begin, all elements of the previous stage must have been finalized. Take a standard mini-ultimatum game with two players, where a proposer decides how much of a given pie to share with a responder, who can accept the offer or reject it. In case of rejection nobody gets anything. Played simultaneously with the use of the strategy method (on the responder side) the decision making can be implemented in one stage. A second stage then states the results for both players. When the game is played sequentially, three stages are needed as shown in figure 8. Stage 1 contains the decision of the proposer, while stage 2 contains the decision of the responder, who is informed about the decision of the proposer first. Stage 3 would then display the results.

Lecturer and Participant View. classEx distinguishes two views - the lecturer or experimenter who runs the game and the participants who take part in the game. For each view a broad range of elements can be added. The lecturer view is mainly aimed at starting the game, controlling the experimental flow and viewing the results.

Element. Each stage consists of one or more elements. These elements can be either input or output elements or little programs for calculation purposes. Due to the restricted space especially on smartphones, elements are standardized with respect to form and layout. The most important elements are the input elements as they are the placeholders for different input fields, which gather all the decisions made. Hereby, inputs can be a discrete set of choices as is the case with select lists or single and multiple choice questions. Also, textual input with a control of the minimum and maximum length is possible next to different forms of numeric input like number fields and sliders. Additionally, random draws are another type of input that can be used in classEx. For the lecturer the main elements are start buttons which allow to start a stage and thereby to end the previous stage. For the last stage the lecturer normally uses result elements to display the output of the game. Thereby he or she can choose among histograms, bubble charts, pie charts and time lines. Another special element displays the payoff codes to participants.

Roles and Groups. classEx allows the experimenter to define different roles in the game. Each role may have a different task and different decisions to make. Players can also be matched into groups, which can contain one or more players of a certain role. By default

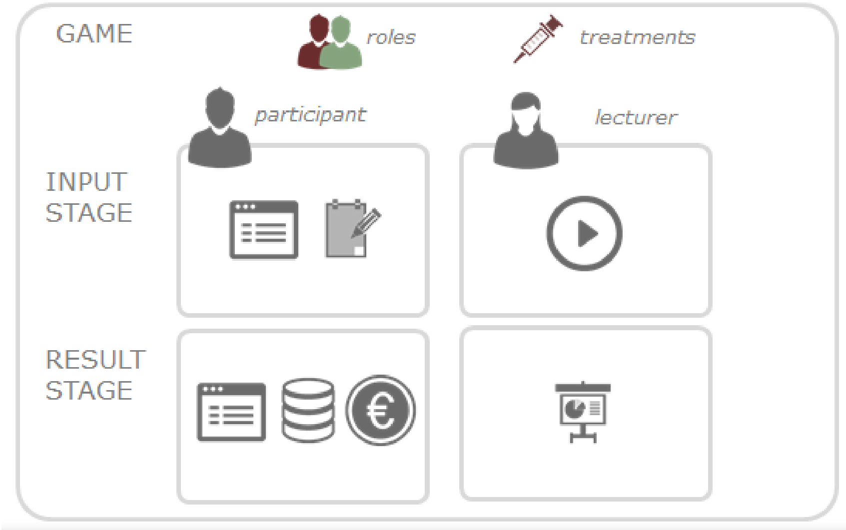

Figure 7: Two Stage Game in classEx

Figure 8: Three Stage Game in classEx

there is only 1 group, such that all players interact in the same group (like in the first two examples in section 2).

Treatment. In addition to groups, there are two ways to implement treatments in classEx. A within subjects design can easily be modeled by a sequence of stages or games. For a between subjects design private information can be used as shown in the first example in section 2. The participants can be split into groups of equal numbers. In each group they can get different private information, different payoffs associated with a strategy choice or interact in different types of groups. This offers the possibility of playing different treatments simultaneously in the same lecture hall and allows for an immediate and direct comparison of treatments. A special need arises from the fact that the amount of participants in the classroom may vary. Students might leave the room earlier or arrive later or an uneven number of participants may take part. classEx offers different methods to deal with this. Decisions of other participants can be doubled with a clone being matched to excess participants. This makes sure that students always get feedback, which can be important for teaching purposes. In case of sequential games, an alternative may be to create random decisions. Additionally, participants with no partner may be excluded from the further game. Certainly, cloned or random observations must be deleted prior to using data for research.

5. Research with Classroom Experiments

Although classEx is mainly used for teaching purposes, it can also be used in research and offers an alternative way of collecting data outside the laboratory. In contrast to the teaching scenario, the immediate display of results is of lower importance for research purposes. The remaining components can be used in the same way as described before. Several arguments regarding the use of classEx for research are discussed in the following.

Costs. Classroom experiments provide an inexpensive method for assembling participants. In the lab, a show-up fee must be paid that compensates participants for costs and time of travel, the time required for waiting outside the lab and allocating subjects to respective laboratory spaces, the subjects effort for enrollment and the risk of not being selected if too many show up. These costs are avoided in the classroom because subjects are already located in an environment where their attendance can be made use of free of charge. Administrative costs for assembling and managing a pool of subjects are also avoided. There is no need for deleting outdated addresses and disqualifying members for failure of showing up. This avoidance of costs increases the attractiveness of the classroom for experiments.

Self-Selection. Participation in the laboratory is voluntary. Subjects decide whether to join a pool that receives regular invitations to experiments and, when invited, whether to react fast enough before all others do. Both decisions are sensitive to a variety of individual characteristics. This has raised doubt whether the preferences and cognitive abilities of volunteer participants are representative of the population from which they are drawn. If not, laboratory experiments would suffer from a selection bias. For example, List (2006) observes that sports-card sellers who declined to participate in a laboratory experiment behaved in an (insignificantly) less pro-social manner when their behavior was observed in a parallel field experiment. Eckel and Grossman (2000) find differences between volunteers for a lab experiment and participants in a classroom experiment, observing that the latter pool was more generous and more affected by non-monetary incentives. Contrary to these findings, Cleave et al. (2013) do not find significant differences in experiments related to social and risk preferences. Still, concerns with respect to self-selection are numerous and these concerns can be mitigated by employing a pre-selected audience.

Pool. Experimental laboratories tend to be located at universities and the associated pool of participants consists largely of undergraduate students. This has led to criticism with respect to the external validity (Levitt and List, 2007). Would ordinary people or market participants behave just like students do? Different pools are commonly difficult to assemble. A broader pool is often approached for simple one-shot experiments. Examples of such a pool are readers of newspapers (Güth et al., 2003, 2007). classEx can provide access to broader pools of subjects who have a mobile device. It can be employed at sports events, music festivals or trainings of corporate salespersons. It thus allows for an easy access to a broad pool of participants. On the downside, the pool is limited to those who have a mobile device. Recent statistics show smartphone penetration rates of 60-70% for North America and Western Europe and increasing trends for the next years (GSMA, 2013, 23). Thus, over time this limitation will become less binding.

Environment. The laboratory is an environment where subjects know their behavior is being monitored, recorded, and subsequently scrutinized. Subjects sense this scrutiny and may bring their behavior in line with social norms or moral considerations (List, 2006). This level of scrutiny is an inevitable consequence of a controlled experiment (Harrison, 2005). But the degree to which subjects feel monitored may increase further in an artificial laboratory environment (Levitt and List, 2007, 158, 170). The classroom is less artificial and brings the environment closer to that of the field.

Double blindness. Subjects may feel that they play a game against the experimenter, which could lead to the effect that their sympathy with the experimenters research or their desire to oppose may overshadow their incentives. This is an issue also raised by Levitt and List (2007, 159). At first glance, this problem seems to be aggravated in a classroom environment. Researchers who run their experiment in class may present a biased description. This parallels the problem of medical drug trials where administrators may treat subjects differently, disappointing those who get the placebo. But there are two ways how this problem can be ameliorated in the classroom. First, treatments can be run simultaneously in a single classroom so that differences across treatments cannot be induced by differences in the way an experimenter treats subjects. Second, an experimenter may abstain from describing the experiment. Delegating this task to an administrator would parallel the system used in medical drug trials. Experimenters would provide written instructions to an administrator, who reads them out loud in class. These instructions would be identical for all subjects. Administrators might even be left ignorant about differences across treatments and even about the goals of the experiment in order to avoid subconscious manipulations of subjects.

Doing the right thing. The classroom is devoted to a certain area of study where subjects seek to comprehend and pass a final test. Participants may think they are participating in a comprehension task in which they seek to prove their qualification. This presents a problem to the validity of experiments because regular monetary incentives are confounded with non-monetary rewards that are outside the control of the experimenter. An experimenter may thus avoid using his or her own courses and approach colleagues who teach unrelated courses for running an experiment.

Valuation. Subjects can be provided with monetary incentives in a classroom experiment such that the induced valuation corresponds with the incentives that one encounters in the field. classEx allows assigning a winning code to any number of participants with a monetary payoff that corresponds with the gains from playing. This code can be presented to a third party (potentially the facultys secretary) who can be left ignorant about the nature of the experiment. This brings incentives in line with those commonly provided in the lab.

Design contamination. In the classroom, knowledge on treatments might diffuse. Subjects might observe that they belong to different groups and that there is a difference between the treatment and the control group. Knowledge regarding the differences might spill over. Participants behavior would then be overshadowed by this knowledge rather than being influenced by the treatment effect alone. In the lab, such design contamination can be easily avoided by disallowing uncontrolled communication between subjects (alas, communication across sessions is more difficult to avoid). In the classroom, sessions can include many participants at once such that a single session in a large lecture hall suffices for a complete experiment. Participants are randomly assigned to treatments within a single session. This approach of running an experiment in a single randomized block avoids design contamination across sessions. But design contamination within a session presents a problem if participants cannot be kept from communicating and from observing their neighbors behavior. There are at least three methods for ameliorating this problem. First, less crowded classrooms can be brought closer to lab conditions by asking participants to sit further apart. Second, treatments can be assigned to different sessions that take place in different classrooms. The method would thus be to randomly assign entire clusters of classrooms to treatments. But this solution is not easy to implement. It involves problems of design contamination across sessions and it involves effort to avoid multiple participation of students. Also, the resulting test statistics lose power because the standard error depends on the number of clusters in the experiment and less on the number of individuals (Rhoads, 2011). We therefore opt for a third method. Participants may be screened ex-post with respect to whether they communicated with their neighbors, observed or heard how their neighbors played or felt their own behavior was observed by others. This type of ex-post screening has been suggested by Duffy (2011) for internet-based experiments, which face similar problems of design contamination. We propose that the third approach is a feasible one when spillover effects are considered to be small (Schochet, 2008). Explicitly asking subjects not to let others look at their smartphone and equally requesting to respect others privacy may be a method for ensuring spillover effects to be at such a low level.

Communication within treatments. Some level of communication remains unavoidable in the classroom, even if experimenters ask participants to remain silent. This brings about three problems. First, there is the risk of communication between subjects who are matched with each other or who believe they might be matched. This might induce higher levels of cooperation because the communication facilitates collusion. Single blindness would be violated and, for example, higher levels of fairness might result because participants feel scrutinized by other participants. The second risk is that planned behavior or expectations vis-à-vis others are announced by participants. This might induce herding behavior and create focal points for coordination. Third, communication has been found to increase individuals level of reasoning and the avoidance of dominated strategies (Charness et al., 2007, 2010; Cooper and Kagel, 2005). While communication in this case tends to improve understanding, it would be problematic if experimenters failed to control for the level of communication, being thus unaware of its consequences. As mentioned previously, asking participants to sit further apart represents one method, screening participants ex-post is another method for ameliorating this problem. The latter allows experimenters to control whether communication existed and the extent to which it impacts behavior.

Real counterparts. Participants in the lab may sometimes doubt they are matched with a real partner. Instead, they might fear they are being deceived and confronted with a virtual counterpart. This fear is likely to be less severe in the classroom for two reasons. First, all participants see others carrying out some type of task. This increases their confidence of being matched with a real partner. Second, all subjects participate with their own mobile device, which enhances sentiments that their devices are not manipulated and that other forms of manipulation are also less likely.

Social distance. A final issue with respect to the classroom is that it commonly involves lower levels of social distance. In contrast to the lab, participants can see all other participants and are distantly acquainted with them. This per se is neither an advantage nor a disadvantage. But it should be kept in mind when comparing results from the lab with those obtained in the classroom and it should also be considered when judging the external validity of classroom experiments.

To summarize, employing the classroom for experimental research requires some particular precautions. But when done properly, classEx can help researchers avoid some of the hazards and reap the benefits of a low-cost subject pool.

6. Conclusions and Outlook

classEx provides lecturers with the chance to improve interaction in the classroom. It is designed to incorporate experimental needs and practical software implementation issues. Standard open formats allow a broad participation and the standardized layout and caching mechanisms enhance a fast and mobile-adapted communication. Easy access and the possibility to distribute real payoffs increase participation while a flexible architecture guarantees different forms of games to be implemented on a centralized framework.

When using classEx for research we highlighted some of the advantages, such as the low costs, a less artificial environment, avoidance of self-selection and access to broader pools of participants. We described how double-blindness can be preserved and incentives be provided. Finally, we showed how the disadvantages related to design contamination and uncontrolled communication can be ameliorated. Overall, we thus conclude that classEx helps in using the classroom also for research.

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Appendix A. Technical Data Model

The architecture can be represented with an entity relationship model (Chen, 1976, ERM) which may be of interest for technically oriented readers. An ERM displays all relevant entities to be stored in a database (see figure A.1). The gray shaded area indicates the entities which constitute the game structure. The other entities store the results. Entities are connected by a relation, which indicates how many instances of an entity can be connected with another entity. For an introduction to ERM modeling see Thalheim (2000).

Games consist of various into stages. Normally, there are more than two stages and a game is characterized by ending with a calculation and/or the display of results. Each stage consists of one or more elements for the lecturer on the screen and the subjects on their mobile devices. Elements may be text elements, input elements or result elements. An input element may contain several input fields, i.e. several decisions are asked at once. Depending on the type of input field such a field may have input arguments, if a discrete decision from a limited set of choices has to be made. For continuous data input (e.g. numeric) or text input no input arguments are needed. All inputs made are saved as decisions of a certain player. As players may take part in different games, each realization of a game is labeled as run to distinguish decisions from one execution from decisions of other executions of the same game. In order to organize games, they are linked to a course or lecture where they are used. As classEx also allows for exchanging games, a game may be linked to several courses.

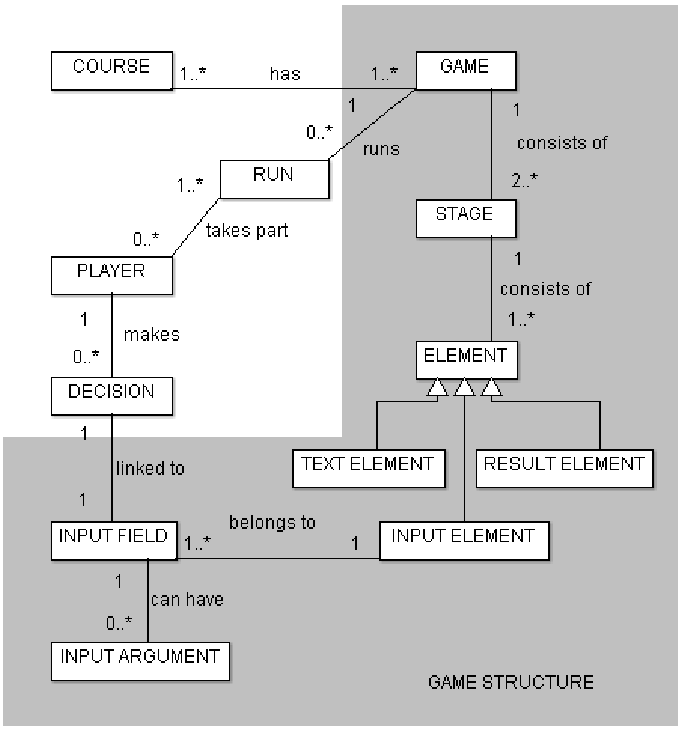

Figure A.1: Architecture