TECHNISCHE UNIVERSITÄT DRESDEN

Professur Rechnernetze

Faculty of Computer Science Institute of Systems Architecture, Chair of Computer Networks

Extended Abstract of the Dissertation

ANALYSES ON TECH-ENHANCED AND ANONYMOUS PEER DISCUSSION AS WELL AS ANONYMOUS CONTROL FACILITIES FOR TECH-ENHANCED LEARNING

Dipl.-Inf. Tenshi Hara

Submitted to Technische Universität Dresden on 18 March 2016 in partial fulfilment
of the requirements to obtain the degree 'Doktor-Ingenieur' (Dr.-Ing.).

Supervised by:
Prof. Dr. rer. nat. habil. Dr. h. c. Alexander Schill

Subject Consultant (Fachreferent):
Prof. Dr. rer. nat. habil. Hermann Körndle
(Department of Psychology, Chair of Learning and Instruction)

External Reviewer:
Univ.-Prof. Dipl.-Ing. Dr. Andreas Bollin
(Alpen-Adria Universität Klagenfurt)

‘Tell me and I forget, teach me and I may remember, involve me and I learn.’

Benjamin Franklin

MOTIVATION

Over the last decade, a growing percentage of young adults attend universities. Simultaneously, drop out rates increase and fewer enrolled students actually attend on-site activities. Statistics show that young professionals consider less than a third of their qualification to originate in their university education [BBF14]. As knowledge and lecture material is available ubiquitously, some students do not see benefits in attending fundamental classes. However, less on-site interaction correlates with poor exam results and ultimately higher drop-out rates. Amending classic courses with interactive learning tools, ideally activating on a meta-cognitive level, supports students' self-regulated learning processes [ZBPZ00], making them experience importance and value of own decisions based on realistic self-assessment and self-evaluation. Students' own mobile communication devices can be used as second screens to enhance the learning experience. This approach has been successfully used in university readings (e.g., with clickers [BSR13], personal response systems [MC11] or audience response systems [Cal07]). This work of research aims to adapt these tools, other tools, and combinations thereof to tutorials, in which students work on tasks and discuss with tutors in order to train and consolidate knowledge that had been introduced in readings. The results presented in the following might be adaptable to other class types with minor alterations.

1 OBJECTIVE

The objective was to implement a learning platform for tutorials based on modifications of existing technologies developed for readings. It was to address problems derived from learning psychology with the means of computer science. In order to achieve the objective, a set of working theses was derived, serving as guideline through the course of conducted research and experimentation. All but the last working theses could be proven. With respect to anonymity, partial inversion of the last working thesis should be considered.

Working Thesis 1 (Integration): If and only if integrated into the curriculum, tools yield a unique feature to distinguish university courses from (free) online courses.

Working Thesis 2 (Transitivity): Encouragement of autonomy can be easily transferred into the online medium if and only if didactics concepts are preserved in tools selection and/or implementation.

Working Thesis 3 (Incidentalness): The impact of tool utilisation correlates with the feasibility of incidental tool utilisation.

Working Thesis 4 (Anonymity): While capability of anonymous tool utilisation provides additional incentive for *regular* tool utilisation by students, provision of anonymity is required for *intensified* tool utilisation.

2 EXISTING CONCEPTS

Based on Mazur's *peer instruction* (PI), in combination with didactics research on self-regulation and motivation, a concept of tech-enhanced tools was derived.

2.1 Self-Regulation and self-regulated Learning (SRL)

As is true for volition as an inner state of a person, self-regulation is a 'self-directed and feedback controlled [. . .] part of a general social cognitive theory of behavio[u]r' and that 'regulatory skills, or lack thereof, are the sources of our perception' [ZBPZ00]. From a social cognitive perspective, self-regulation is a triadic process interaction of personal, behavioural, and environmental nature. Self-regulation includes behavioural skills and a priori knowledge of agency to enact these in relevant contexts, as well as a deterministic sense thereof. With respect to (personal) goals

(⇝ section 2.6), self-regulation includes self-generated thoughts, feelings, and especially planning and conduct of actions aimed at fulfilling those goals.

Analogously to open loop control, self-regulation is dependent on cyclical processing, where feedback from a prior performance is observed and evaluated in order to adjust the next, or if applicable the current, iteration. Forethought, performance or volition control, and self-reflection are the iterative phases of self-regulation. Forethought involves processes preceding efforts to act, building up volition and moving toward a fiat tendency. Performance or volition control involves motoric process affecting attention and the action itself. Self-reflection influences the individual's perception of and response to the outcome of the action, which in turn impacts forethought on follow-up processes. Any outcome of an action taken is evaluated and benchmarked against an inner set of goals, which are of performance or mastery nature. Replacing the universal terms *action*, *task*, and *outcome* with terms associated with learning and teaching, this process is applicable to educational settings. Teachers and students can (and should) adapt their conduct on a self-regulatory basis in order to maximise efficiency of education.

2.2 Peer Instruction (PI), Peer Discussion

Conceived in the 1990s, peer instruction (PI) is a well-established method of designing on-site lectures and has been under continuous research [Maz97, CM01, CWFM07, LMW08]. It is applicable in a wide range of situations and for a large scope of different class sizes [FCYM00]. Frequent recollection of material during classes can be arranged in different ways, from the 'bonbon model' and similar constructs [Mar03, Sis12, Mie07], a sandwich [Wah13], to a circle [B_R01] with opportunities for appropriate incentives [HG87]. The goal is to involve all students as good as possible in the lecture by tasking each individual a mandatory explanation of their understanding of the presented concepts to their fellow students (peers). Application of the concept requires a structured test before these peer activities that is addressed at all students equally.

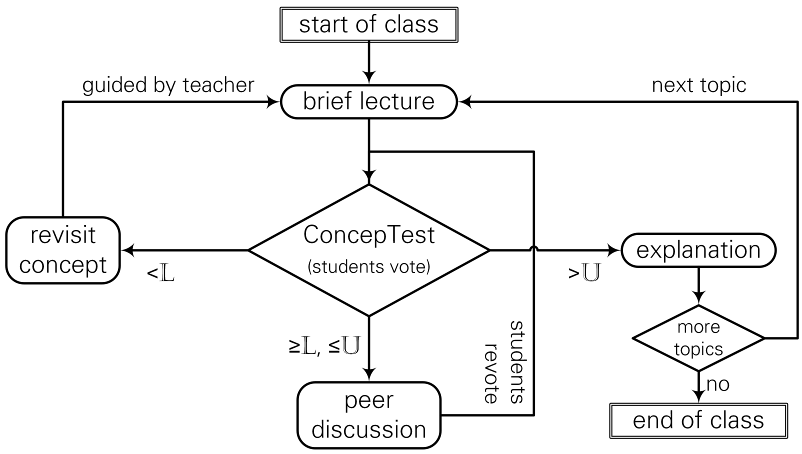

Figure 2.1: Basic flow chart of PI. The thresholds $\mathbb{L}$ and $\mathbb{U}$ need to be determined, but can be adjusted dynamically.

Prior to any PI lecture, students are required to read prepared material on the topics during an at-home preparation phase. Traditional linear presentation is divided into a series of short (self-contained) topics, therein following a defined set of rules known to the students. Each short presentation is followed by a directly related conceptual test ('ConcepTest'). All students should submit answers within a minute or two. The answers are not graded and do not influence the students' assessment, but are utilised to benchmark their (current) understanding of the topic. The topic is revisited under supervision of the teacher if less than roughly 30% of the students successfully pass the ConcepTest. The next topic is introduced if roughly 70% of the students successfully pass the ConcepTest. Any outcome within the thresholds leads to the students discussing their answers with their (direct) neighbours in *peer discussions*. The students try to convince each other of the correctness of their own answers within two to four minutes. This addresses the learning tiers expansion, construction and the ability to explain and discuss. The teacher roams through the class room and listens to as many discussions as possible, taking note on good and bad arguments. After the discussion time, the teacher ends the discussion and calls for the students to answer anew. Students can change their answers, especially if their position has changed. Afterwards, the teacher explains the correct answer and moves on to the next topic.

2.3 Learning Process Supervision (LPS): Learning Demand Assessment (LDA)

Traditional forms of instruction are more and more replaced by a learning process supervision (LPS) [Bau07, BEH+96]. LPS consists of several steps: demand assessment (LDA), path determination, task design, progress observation and support, result evaluation, and result documentation. The first two yield equally shared activities for teachers and students, the latter four involve the teachers. These six steps roughly represent the ideal chronological execution. However, they do rely on each other and are never clearly separable. In LDA, the student's individual learning goals are determined together with the teacher. Based on the learning demand, teacher and student stipulate a learning convention as well as a learning path. One or more suitable tasks for the learning path are selected. The teacher needs to observe the student's learning with the given tasks, assisting with learning barriers. After each task is solved, teacher and student evaluate the results. Finally, the teacher assists the student in documenting their results in order to allow and foster consolidation and dissemination of the acquired knowledge.

As LPS is focussed on individual student development, it requires a systematic and continuous redefinition of learning goals. The redefinition as a per-demand adaptation has to be individualised for each student's personal strengths as well as weaknesses. To optimally adapt a student's learning path, the teacher must understand the student's learning behaviour. Student and teacher together need to know how they can optimally encourage learning processes. An LPS aimed at fostering SRL processes (↝ section 2.1) must focus on the question of what is necessary in order to enable the student to autonomously identify their own learning demand. Teacher and student together decide changes to the learning path and any consequence is within the student's responsibility, which can either foster their self-confidence or demotivate them (positive vs. negative self-regulatory effect). Teachers aim to ensure a positive outcome and disclose all learning path related observations and conclusions in order to maximise positive incentive.

2.4 Cognitive Activation

Cognitive processes are an important part of decision making and motivational processes, as learning requires constant linking of new information to already present information. Students are able to learn more efficiently when they are enabled to use incoming information to activate information they have previously consolidated. Any form of teaching is *cognitively activating* when it stimulates students to actively engage new information in a personally optimal fashion (for example [BK00]). This can be considered evolutionary learning [HPR07], but requires consideration of learning processes to be constructivist. Therefore, solving problems or exchanging solutions with peers seems to be better suitable than knowledge derivation along open questions. This should not be mistaken for the presence of competence [Leu11]; rather, activation and competence are complementary concepts. While activation aims at effective knowledge transfer, competence aims at knowledge consolidation. Activation is a means for effectively achieving in all areas of competence. Learning goals must be devised in context of desired competence, based upon which suitable activation strategies must be considered.

2.5 Learning Platforms

Interactive learning platforms, e-learning tools as well as interactive tutorials benefit from loose coupling of time and space, options for own learning speed, progress-independent selection of topics, repetition of topics, and low costs. However, with a lack of instructor feedback, they can have a negative impact on the learning process [CM01]. Strategies for controlling of learner motivation must be developed, aiming at positive incentives [CJ10] and high motivation levels. Timing and number of incentives need to be well-considered. Carefully designed platform concepts dictate the means for motivational incentives [LLY10].

2.6 Motivation Control

Traditionally, the fundamentals of motivation are divisible into motive, motivation, volition, and action. Each fundamental is based on the preceding. Starting with the motive, it represents an (internal) attitude toward an objective a person is aiming for. Motives are not directly observable in general; they can only be deducted from behaviour and actions. Hence, any motive may induce an action readiness. Such induction is called motivation and is always strongly correlated with a definable situation, restricting its occurrence to a very narrow time frame. Thus, motivation is commonly defined as either intrinsic or extrinsic. Regardless of type of motivation, once motivated, a person may develop an intent to act, which is the first step in the process of volition which – besides the intent – includes planning the action itself, and finally an impulse that leads to overcoming underlying action thresholds and initiating the actual action. Finally, this action is any type of observably planned, subjectively reasonable and purposive behaviour.

In order to influence a learner's motivation positively, the process leading from motive to action must be considered. In [HG87] a volition model with significant pre-decisional and post-decisional phases is suggested. It provides a starting basis as the model allows envisaging four phases, each underlayed by one or more motives, leading to an action and/or follow-up actions: consideration, planning, action, and assessment.

2.7 Virtual Interactive Whiteboard Systems (V-IWB)

Definitions on virtual interactive whiteboards vary. Alas, it is imperative to distinguish them from regular interactive whiteboard (IWB) solutions with a clear definition. Therefore, a virtual interactive whiteboard (V-IWB) shall be an interactive whiteboard utilising a virtual display area (website frame, second screen, ...) instead of a physical display. V-IWBs are discriminable into different types of collaborative systems, namely *personal notebook*, *personal bulletin*, *shared notebook*, and *shared bulletin*. For obvious reasons all types of V-IWB are suitable for learning platforms as they help students organise their (virtual) graphical work space (canvas). However, the bulletin and especially the shared types encourage group activities which are important for SRL with regards to performance in comparison to peers. Utilisation is not limited to a few representative students in front of the class, but open to all attendees. Furthermore, students not in the same classroom are able to partake in whiteboard activities.

2.8 Audience Response Systems (ARS)

The best conceptual ideas on self-regulation are useless if students have no means of influencing their learning environment. It is desirable to increase interactivity in order to give students a fulfilling learning experience. Amongst a vast range of possibilities to influence learning environments, systematic approaches are promising. Such systems range from simple 'clicker' systems [BSR13, Dun06, Lan10] for voting or polling, to complex 'personal response systems' (PRS) [MC11] for individual responses, and 'audience response systems' (ARS) [Cal07] for group responses. ARS provide feedback to the lecturer during classes by having the audience vote on questions or poll on topics. By providing this feedback channel, students get more immersed in their learning environment. The lecturer in return gains valuable information about the audience's knowledge and attitude. The basic functionality of all systems is similar: the lecturer amends the regular teaching material by preparation of one or more questions that shall be presented to the audience at defined times. These points in time should also be defined by the lecturer. At the beginning of class the ARS is introduced to the students, who are asked to submit answers to the above mentioned questions when they are displayed. During class, processed results can be presented to the audience via the regular or a dedicated presentation screen. This allows the lecturer to adapt their presentation based on the audience's answers. Inclusion of ARS over the course of an entire semester can lead to increased motivation, higher attendance rates, and better exam performance [MSD+09, WB13, FWB13, PB09, Dun06, Cal07, BGLD06, Lan10].

2.9 Cognisant Incidental Utilisation (CIU)

Assuming the main means of tutorial conduct remains to be the black- or whiteboard, second screens (for example [LA13]) provide an additional interaction means for students and tutors and are supposed to be cognisant incidentally utilisable (CIU), namely by students making the voluntary but cognisant decision to utilise their device when they incidentally want to, not when the device calls for their attention. Two separate concepts are combined into one action concept, namely *cognisant decision making* and *incidental utilisation*. The basic idea is to have all phases of decision making described in section 2.6 be cognisant, and combine them into the utilisation (the action) in a way that it becomes incidental on a conscious level, meaning it *is perceived* as incidental on the conscious action and decision making levels. In principle, a person engaged in an activity consciously decides whether they are willing to engage in a second (in-parallel) activity, and are aware of the consequences of that second action's conduct on the primary action. They decide if they can afford to split their attention on the activities. CIU is a design principle rather than an achievable conduct. As visible in Figure 2.2, CIU bases on three pillars of awareness and choice, hence proper introduction to tools and clear announcement of utilisation rules support achievement of a maximum of CIU contingent. The required separation of the involved roles, one on the CIU supporting side, one on the CIU striving side, is easily achieved in educational tools as there are two distinctive roles anyway: teachers and learners.

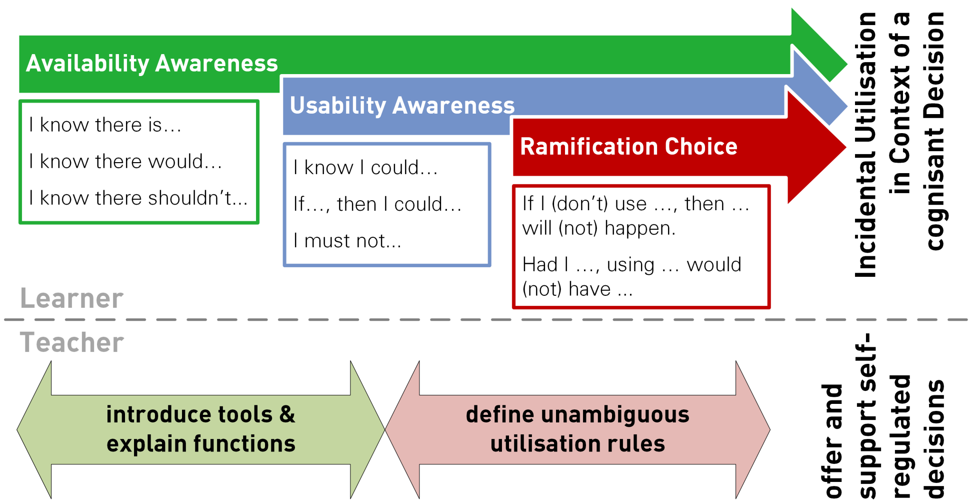

Figure 2.2: Cognisant Incidental Utilisation: three columns of CIU from the learner's perspective (top) and associated teacher's tasks (bottom).

2.10 Knowledge Exchange Hubs

The general concept of knowledge exchange hubs is to allow expert discussions on questions, provide a means to collaboratively discuss, allow determination of solutions to problems, and finally to preserve discussions. This final aspect, namely preservation, can be considered imperative, as same or similar discussion recur over and over again.

There are many representatives of knowledge exchange hubs with community votes (and potentially with pseudo anonymity). All in common, any question can be asked within the platform as community-driven self-moderation takes place. W.l.o.g., any question unrelated to wanted topics (for example spam) will receive negative comments and down-votes, hence removing the question from attractive search result positioning. The votes represent each individual's attitude toward a contribution. The initial creator of a new topic (in general by submitting a question) is able to mark answers as 'helpful' for the problem, allowing other users easier access to solutions. Up-votes and down-votes are added and accumulate in a score displayed next to a contribution. Additionally, based on replies, votes and 'helpful' markers, topical discussion are prominently displayed in topic streams for easy access. The scores can also be utilised to display mastery of certain knowledge areas or advanced performance on certain problem within user profiles. This helps addressing performance as well as mastery goals originating in self-regulation. Often these aspects are additionally addressed by the addition of gamification functionality.

2.11 Visible Learning

Visible learning [Hat09, Hat13] represents facts of current education aspects derived from results on a vast set of meta-analyses related to education. It is one of the largest, if not even the largest, collection of research about efficiency in education based on actual data. From the data a comparison of effect sizes of different educational aspects within their respective context is derived. Effect sizes are provided as a numerical value where an effect size of .5 is equivalent to a one grade leap at GCSE, an effect size of 1 is equivalent to a two grade leap at GCSE, an effect size is the result of a normalised and averaged value of a 'number of effects' from 'well designed' studies, and an effect size above .4 is above average for educational research. As the effect sizes originate in the vast dataset mentioned, any educational concept in use will somehow correlate to the visible learning results. For the dissertation, a subset of eighteen visible learning effects (VLE) is considered:

- VLE01: proficiency level self-assessment,
- VLE02: formative assessment of class,
- VLE03: micro-teaching,
- VLE04: influence class behaviour,
- VLE05: clarity of teacher,
- VLE06: feedback,
- VLE07: promotion of vocabulary,
- VLE08: promotion of creativity,
- VLE09: non-labelling of students,
- VLE10: promotion of visual perception,
- VLE11: class cohesion,
- VLE12: peer influences,
- VLE13: class management,
- VLE14: learning in small groups,
- VLE15: motivation,
- VLE16: perceived teacher quality,
- VLE17: angst reduction, and
- VLE18: extra activities for highly skilled students.

3 GLOBAL PICTURE & PROTOTYPE

As it is utopic to assume to be able to address all aspects of educational problems, this research focuses on a selected subset of topical interests, mainly presented in the previous sections. Having students be able to autonomously perform certain tasks requires effective transfer, consolidation and application of knowledge. All three factors can be addressed by efficient design of scenarios. PI primarily addresses transfer, but can also be applied for consolidation. SRL assists students on the receiving end of transfer and is capable of fostering effective consolidation. Cognitive activation addresses these stimuli and therefore, directly influences effective consolidation and application. Strangely enough, with respect to the means of computer science this simple correlation has not yet been thoroughly investigated. It is fair to postulate that intensive research is desirable at this intersection of didactics and computer science. The intersection of selected involved concepts and technologies is depicted in Figure 3.1.

Knowledge application is considered out of scope; the focus is on transfer and consolidation. As transfer has been under heavy investigation, transferring ideas to consolidation is worthwhile. Due to significant overlap in concepts and technology, this should be possible with reasonable effort. Partial aspects of knowledge application drop off as a by-product. This is especially true for peer activities like peer discussion. Efficient application of knowledge yields good arguments for these discussions.

Based on the previous investigations into existing concepts and related work, a set of assertions on tools within the above defined scope was conceived. The tools described in the assertions can be divided into three categories: tech-enhanced and anonymous peer discussion means (teaPD), anonymous control facilities (aCF), and learning demand assessment (LDA). In these three categories, teaPD includes a conceptual conversion of the assertions on (peer) discussion

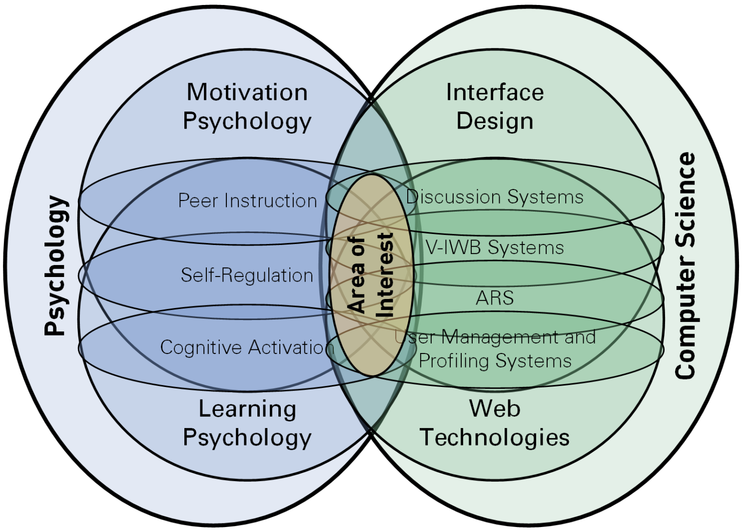

Figure 3.1: Schematic display of the intersecting concepts and technologies investigated.

systems as well as the V-IWBs, aCF includes an emergency brake (a special type of ARS) and an evaluation system, and LDA consists only itself. The concept is extensible by other tools, but also by retroactive revocation of anonymity which students have requested (⇝ Figure 3.2). The anonymous provision of the given combination of tools via second screen under CIU allows addressing the VLE listed at the end of section 2.11. The concept was implemented in several prototypes.

4 INVESTIGATED TOOLS

Experiments with the before mentioned prototypes were conducted during real tutorials in a control-group setting, namely having one tutorial group use the prototypes, while another group did not. A third group used selected tools within the prototypes only at specific points in time, mainly in order to determine the correlation of tool utilisation with certain types of tutorial tasks. Students were asked to voluntarily provide feedback on different aspects of the prototypes based on a platform feedback sheet. Additionally, oral interviews were conducted. Some students provided feedback on minute papers.

4.1 Peer Discussion System

The peer discussion system closely follows the concepts of knowledge exchange hubs, including topics, questions, answers, comments, votes, and 'helpful' markers. It addresses VLE01, VLE03, VLE05, VLE06, VLE07, VLE09, VLE11, VLE12, VLE14, VLE17, and VLE18. The tool was well received by students and proved utilisable in two distinct settings: as a peer discussion means for anonymous discussion, especially allowing students to discuss with students other than their direct seating neighbours. The second setting were low interactivity tutorials that have either very low activating interaction between the tutor and the students, or when the tutorials were so crammed with material to be covered that there was little time for interaction.

Astonishingly, the discussion system proved to be a self-moderating tool as students would down-vote any spam or unwanted contribution. Six different combinations of availability settings were investigated for the discussion tool:

- **PDS1**: everything enabled – the default combination
- **PDS2**: no new topics, no new replies – pause: allows the tutor to pause the discussion system while at the same time still allowing the students to vote on existing contributions.

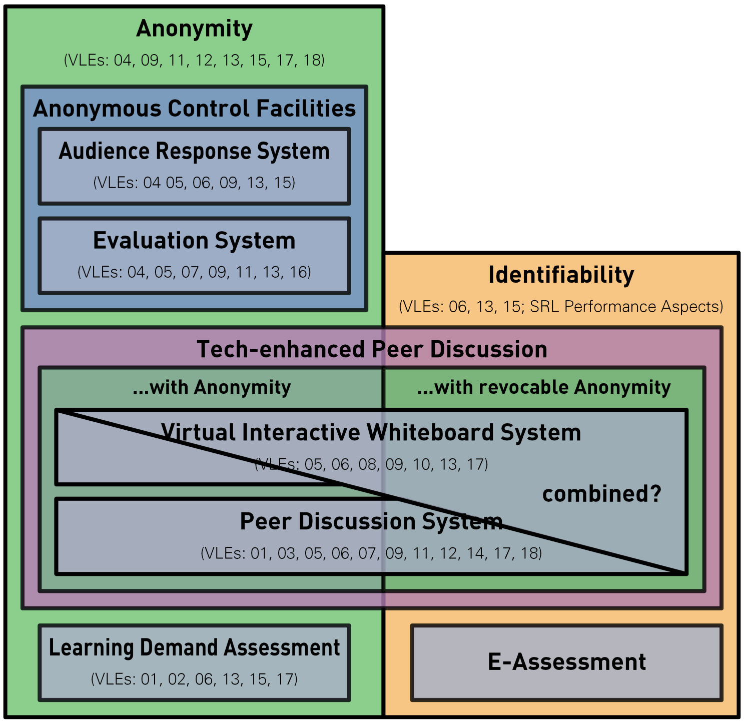

Figure 3.2: The discussion and control design with retroactive revocation of anonymity.

- **PDS3**: no new topics – only existing discussions: allows the tutor to call for discussions to come to a conclusion. This was badly received during lectures, but well appreciated for post-class off-site conclusion of discussions.
- **PDS4**: no new replies – issue collection: allows tutors to collect open issues without having students engaged in discussions. The tutor can then answer the top N ($N \in \mathbb{N}$) issues whenever time permits. This was badly received during tutorials, but well received for pre-class preparation phases.
- **PDS5**: no new votes on topic creators, no new votes on replies – the brainstorming combination: Allows students to impartially gather contributions for later sorting and elimination. This setting remains to be tested.
- **PDS6**: no votes on replies – topic-centric: This was very badly received, as the correlation of votes and contributions was lost.

4.2 Virtual Interactive Whiteboard System

A simple implementation of a V-IWB was tested. The tutor was enabled to share especially bad or good contributions with the entire group of students and discuss on that basis. In that way, V-IWB address VLE05, VLE06, VLE08, VLE09, VLE10, VLE13 and VLE17. The tool was very well received by the students and allowed comprehensive discussions, especially in PI settings.

4.3 Audience Response System

The ARS and emergency brake tools address VLE04, VLE05, VLE06, VLE09, VLE13 and VLE15. In a first iteration a fully fledged ARS for real time feedback on volume, speed and perspicuity was provided, but it violated CIU and time correlation proved difficult. It was replaced with a simple emergency brake button, allowing students to raise an issue to the tutor's attention. In combination with pre-defined textual reasons as well as individually assignable free-text reasons, this was well accepted by the students. Furthermore, allowing for the provided reasons to automatically create a new topic in the discussion system enabled students to discuss among their peers the validity of the emergency brake utilisation.

4.4 Evaluation System

As ARS and emergency brake tools are able to only address a limited range of quality aspects of tutorials and are bound to close timely correlation, another aspect of aCF is represented by an evaluation tool that addresses VLE04, VLE05, VLE07, VLE09, VLE11, VLE13 and VLE16. It allows to span the bridge between immediate feedback and single end-of-semester pen & paper evaluations that provide feedback at a too late time. This provided timely feedback on a variety of quality dimensions to the tutor and benefited both sides. The evaluation tool allowed tracking of the tutorials' quality over the course of a semester.

4.5 Learning Demand Assessment

The implemented LDA tool addresses VLE01, VLE02, VLE06, VLE13, VLE15 and VLE17. It required students to answer targeted confidence questions on the tutorials' tasks before and after each tutorial unit. From the difference in confidence and in correlation to related topics, the tool was able to calculate a learning demand assessment for the students. This way, they were able to receive a suggested topic learning repetition sequence at any time, especially near the end of the semester, thus optimising their learning efforts for exam preparations. As no significant utilisation of the LDA tool occurred, no reliable data for an educated appraisal is available. Therefore, further investigation of LDA is suggested.

5 CONCLUSION

Addressing low attendance and the high drop-out rate among the ever increasing number of university freshmen, the impact of existing concepts and tools for tech-enhanced education was investigated in several experiments. The goal was to increase motivation to attend on-site tutorials, and foster understanding of the importance of fundamental classes, making on-site activities more attractive.

Selected tools based on LPS, PI, as well as SRL, and oriented along a subset of VLEs. Experiments were conducted in order to analyse the impact of ARSs, emergency brakes, evaluations, LDA, peer discussions, and V-IWBs. All tools were investigated under consideration of CIU and an initial assumption of necessary anonymity. Provision via second screen was pursued in order to minimise potential negative influences on the students' learning performance.

The tools investigated for teaPD proved to be very successful in raising exam success. On one hand, the discussion tool was very useful in low interactivity settings as it allowed students to address and partially clear issues in parallel to tutorial conduct. Additionally, it allowed highly skilled students to reduce their idle time, and tutors to focus on the top N ($N \in \mathbb{N}$) important issues as time permitted. Any remaining open issues could be addressed in online after-class sessions, either synchronously with the students online at the same time or asynchronously with them being online at different times. On the other hand, the V-IWB proved very useful for graphic-reliant tasks, allowing easy discussion of canvas-based learning and application.

For aCF, the investigated tools clearly showed that two ends need to be served: first, a strongly time-correlated, almost immediate issue indication, and second, a time-decoupled unit-level evaluative feedback means. The first clearly showing the limits of ARSs in context of tutorials. Instead, a reduction to an emergency brake is the only solution feasible under CIU. The second proved that an issue indicator is not sufficient for the students to point out all issues that may arise. Some issues do not require immediate attention, or do not warrant an interruption of the tutor. These kinds of issues are desired to be corrected from one tutorial unit to the next. Overall, students in the test groups were more satisfied with their feedback possibilities and more motivated to attend tutorials than students in control groups.

The positive results for teaPD and aCF are only achievable under clear definition of utilisation rules, strict enforcement of these rules, as well as corresponding tutorial conduct. Any deviation results in directly measurable negative influences. Thus, not only the students are required to carefully utilise tools, but also the tutors are required to observe the defined rules and react to feedback.

As mentioned earlier, data for LDA were inconclusive and warrant further investigation.

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