Using issue tracking as a groupwork facilitator in education

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Abstract—**In higher education, collaborative work is a prevalent method for skill development and assessment. This approach enables learners to use available time and resources efficiently, supported by peers, for deeper understanding and practical application of learned concepts. However, group task execution reduces individual work transparency. This aspect can be im-proved with the help of IT support, measuring not only out-comes but also individual contributions through task fragmen-tation, responsibility assignment, and performance tracking. In the business world, ticket management systems are commonly used for issue tracking, but less so in education. In this study, we describe integrating issue tracking for project management and communication in a new experimental course. We propose leveraging system data for evaluation. The presented empirical data and experiences could aid stakeholders in similar projects to benefit from issue tracking systems.**

Index Terms—**active learning methods, computer-supported collab-orative learning, education, issue tracking**

I. Introduction

Project-based courses are widely recognized and favored in universities globally, especially in engineering, computer science, business, and design, as they foster critical thinking and lifelong learning often through Problem-based Learning (PBL). In these courses, students collaborate to solve real or simulated challenges, applying theoretical knowledge practically, and developing teamwork and problem-solving skills. They take on significant responsibility for their learning, often working in groups to address real-world issues pertinent to their future careers, thereby gaining a comprehensive and interdisciplinary understanding [1].

The management and passing of tacit knowledge have many challenges, especially in an educational environment, where students have a far more diverse degree of motivation than employees in an actual workplace. Working on a project as a team with the support of a supervisor is among the best ways for students to develop skills that require experience; however, the equitable performance assessment of the individual student proves to be difficult [2].

An experimental project course was launched last year at Corvinus University of Budapest, designed to simulate real-world scenarios and enhance team-based project skills. As part of evaluating this course, the instructors sought to integrate formative evaluation methods to better address the common challenges inherent in such team-based projects. These challenges include the time and resource-intensive nature of the assessment, the establishment of fair assessment conditions and criteria, and the multitude of assessment milestones [3]. Faced with the substantial data need to fairly assess such project contributions, instructors recognized the potential benefits of adopting tools typically used in the corporate world. Consequently, an issue tracking system commonly employed in business environments was introduced, adapted to the academic setting to ensure complete transparency in grading. These are often referred to as ticketing systems, and the rest of the article uses the latter to avoid confusion when discussing the issues solved by the students.

Students were required to track their progress through a ticketing system, which aided in evaluating both the overall project and individual contributions. By making the quality of the ticketing system management a part of the grading process, the students were engaged as active partners in data collection, critical for accurately evaluating their individual contributions and teamwork. This integration seeks to refine the assessment of project-based learning by ensuring fairness and motivating continuous engagement.

Our goal is to develop courses which can prepare students for real life scenarios while addressing the typical issues associated with PBL. Traditional methods lack tools and data for individual assessments, leading to uneven work distribution among team members and the demotivation of students. The introduction of the ticketing system is a novel approach which can improve the engagement and efficiency of students while also providing a basis for fair assessment.

This study aims to verify the positive impact of the ticketing system and to further enhance course quality. We examine individual performance in comparison to other courses along with student feedback and the quality of final projects to assess the added value of our approach. By analyzing data collected from the ticketing system, we refine the evaluation method and propose changes aimed at improving the engagement of students.

II. Background

Active learning distinguishes itself from traditional educational methods by emphasizing student engagement and participation directly in the classroom setting. Unlike conventional lecture-based instruction, where students typically receive information passively, active learning involves students through meaningful tasks that necessitate critical thinking and reflection about their actions [4].

Problem-based learning is a frequently employed active learning method where the process of knowledge transfer begins with a problem definition, which then acts as a moti-

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vational cornerstone for all subsequent learning activities. PBL is first proposed by Neufeld and Barrows in the 1970s [5]. This approach deviates from the traditional passive student role, as students are expected to demonstrate a high level of autonomy based on their previously acquired knowledge and experiences. Within PBL, the typical sequence involves problem identification, group work, research, learning, solution development, and periodic presentations by student groups. The role of the instructor undergoes significant transformation during PBL. While in conventional teaching, instructors primarily convey their knowledge to students, in PBL, instructors adopt the roles of facilitators and mentors [6].

Team Based Learning (TBL) actively engages students in small collaborative groups, focusing on understanding and applying information. Its goal is to develop critical thinking, problem-solving, teamwork, and communication skills, deepening their understanding of the subject matter. [7]. The duration of tasks to be solved can vary based on the employed teaching strategy, ranging from a single class session to a complex project spanning an entire semester. In the university setting, TBL plays a pivotal role in enhancing students' skills by solving complex problems in teams [8].

When teams are assigned the responsibility of solving problems independently, it is easy to conclude that the instructional methodology should be combined with the use of specific roles. Role-Based Learning (RBL) is an educational method where students assume specific roles within a structured activity or scenario, often mimicking real-world professional environments. This approach aims to enhance understanding and skill development by placing students in contexts where they must apply knowledge, make decisions, and collaborate based on their assigned roles [9], [10].

Teamwork utilized in education often faces criticism for potentially leading to uneven distribution of workload and value creation among participating students (free-rider problem), especially when group members possess varying abilities or levels of commitment [11]–[13]. In his comprehensive review article, Davies (2009) systematically addresses critiques and recommendations concerning teamwork, encompassing the nature of assigned tasks, strategies for addressing motivational issues, and other pertinent considerations. Especially in the case of long-term teamwork projects, Kłeczek et al. [14] identified that they often lead to students feeling overwhelmed due to poorly managed workload distribution.

From the instructor's perspective, assessing the outcomes of teamwork, especially when the task involves creating a project workpiece, can be exceedingly resource-intensive [15], [16]. Evaluation may be constrained by the final product, but the need for fair judgment might necessitate accounting for individual performance and active participation within the team. This type of individual performance assessment demands a significant amount of data.

In computer-supported collaborative learning, students ideally engage with tools that prepare them conceptually and practically for real-life challenges. In certain cases, the tools themselves can be considered subjects of the training [17]. The corporate world has long utilized widely adopted solutions for tracking and managing problems to be solved either in teams or individually; these are the ticketing systems, also known as issue tracking systems.

Ticketing systems are pivotal tools in both the IT and customer service domains, designed to efficiently manage, track, and document tasks and issues [18], [19]. Such systems typically record incoming requests, problems, or tasks in a structured manner as tickets. These tickets are then allocated to the responsible party for task completion, who subsequently logs the action, optionally including the time spent.

A ticketing system can prove to be an effective tool for supporting and evaluating student work. By logging and documenting task performance through tickets, students enable precise assessment criteria during evaluations, minimizing conflicts within groups. This leads to more accurate individual and team performance assessments. Additionally, ticketing systems provide insights into student activities, preparing them for future workplace tools.

The widespread use of these systems can enhance academic assessment precision and also sets the stage for broader applications. Captured data, including causal relationships for tasks and solutions, can be used to train cognitive systems like chatbots [20]. The increasing use of generative AI in educational settings expands personalized and adaptive learning solutions [21], highlighting the potential to refine AI's effectiveness in academia.

Our inference is that the implementation of a project course should integrate the best practices of Problem-Based, Team-Based, and Role-Based learning with robust computer support. This setup enables students to manage their tasks (the quality of task management should also be included among the evaluation factors), and it offers instructors complete transparency. This approach shifts the focus of assessment from evaluating the final product to include the process of execution in the evaluation as well. Additionally, extensive data collection paves the way for data mining, which can provide valuable insights into both student and instructor behaviors.

III. Related work

There is a relative scarcity of publications concerning data collected by ticketing systems and the analyzes based on them, especially in a university setting. However, structured information made available by these systems can enable a wide array of data mining tools, including network analysis for uncovering collaboration patterns [22], application of text mining tools [23], [24], and even data-driven predictions [25], extending beyond obvious performance assessment analyzes [26]. The primary reason for the lack of findings is the limited adoption of ticketing systems in education and the business realm. In these areas, their usage is not widespread, and the data they store is often not extensively accessible for analysis due to the proprietary nature of business-related information.

Perera and colleagues conducted research based on ticketing systems and team-based learning [27]. Throughout the study, they monitored the work of 43 students divided into seven distinct groups over a semester. The students collaborated on a software development project across three integrated platforms: a ticketing system, a version control tool, and a documentation wiki. The student groups in this research were homogeneous, meaning every member worked on identical tasks without designated leaders or coordinators. It was pointed out that if a team does not have a designated leader, but a leader stands out from the team in terms of behavioural patterns, this has a positive impact on the performance of the group.

Version control systems, which are commonly used in the business world to track software development activities, are also suitable for measuring individual contributions. In their article, Fernandez-Gauna et al. describes a sophisticated approach by using Git for the automated assessment of team-coding assignments in a university setting [28]. Version control capabilities are leveraged to gather detailed metrics on both team and individual student contributions. Team Performance Metrics (TPM) assess the overall health of the project, such as the percentage of time the code builds successfully and passes tests. Individual Performance Metrics (IPM) evaluate personal contributions, including the regularity of commits, adherence to coding standards, and the effectiveness of each student's code in passing automated tests. These metrics are periodically compiled into reports, offering continuous, detailed feedback to students and instructors. This process helps identify both collective and individual performance issues, facilitating targeted improvements.

It is important to differentiate in the case of team task execution in relation to team composition. In university settings, teams are often homogeneously structured: each student's role is identical, and they participate in solving the problem according to their own motivational and skill levels. In real life, a project team rarely consists of members with identical roles. It is more likely that each member has a designated role, which may rarely or never change during the course of the project. This role-based learning is evident in Sancho and his colleagues' study that focuses on distributed problem-based learning [9]. The learning process described in the article takes place in a virtual world, where instructors assign missions to students working in various roles. The learning process is realized by completing these missions. The study primarily examines students' effectiveness and the architecture of a custom-developed system, emphasizing the distributed problem-based learning through three case studies.

Role-based learning can also be seen as an element of gamification, and in the case of long-running projects, education can be enriched with a number of role-playing games taken from corporate life. Gamification appears in student assessment in the article by Udeozor and co-authors [10]. They propose a Game-Based Assessment Framework and discuss how immersive learning technologies can enhance education but require new assessment methods. The authors propose a Game-Based Assessment Framework (GBAF) that leverages the Evidence-Centered Design (ECD) framework and Constructive The framework collects data through gameplay, providing immediate feedback and aligning game tasks with learning outcomes. The study showed that students' performance improved with these immersive assessments, suggesting that the GBAF is a practical tool for integrating immersive technologies in education.

Overall, there are many studies implementing techniques like TBL, RBL or GBAF to improve the transfer of tacit knowledge while keeping the students engaged. The use of a ticketing system can support these solutions while also addressing the usual issues with objective and fair evaluation of the individuals. However, to our knowledge, the studies addressed in this chapter are the only ones which delved into the possibilities of ticketing systems in education, but they all narrowed their focus on software development related tasks. Our approach aims to be more generalized and flexible in the topic as well as the heterogeneity of individual tasks.

IV. Context and Data

We collected and analyzed data over a semester from the activities of 90 second-year students majoring in Business Informatics. During the classes students were able to gain essential practical experience in the fields of software development and IT project management, building upon their previous studies. The course was launched for the first time, making its execution akin to a pilot project. The main project deliverable is creating a corporate website with e-commerce functionality using a Content Management System (CMS), ideally capitalizing on the abilities they had acquired in their earlier studies. CMS is a software that helps users to easily manage, edit, and publish websites and digital content. It is essentially a web-based application installed on a web server that allows users to create, edit, organize, and share content. The problem was chosen to be non-trivial, not easy to solve even with external help, and to better reflect students' attitudes to poorly structured problems and difficult tasks. During the project, groups of 4-5 students were responsible for the installation and customization of a CMS system, the design of a webshop, and the development of a custom-built module.

For the course, DotNetNuke (DNN) has been chosen, which is a specific example of a CMS based on the Microsoft .NET framework When selecting the CMS to be used for the project work, our specific goal was to choose a relatively well-documented, open-source CMS, but one with low popularity. This reduced the likelihood of students applying ready-made solutions available on the internet without adding substantial value. In the CMS market, WordPress is the most widespread, while according to available statistics, DNN ranks 34th with a 0.16% market share [29]. Despite its low popularity, its development is ongoing [30]. By selecting DNN, we presented student groups with difficult but solvable problems typical of the implementation of CMS systems.

Reflecting on the free-rider problem commonly associated with TBL, we aimed to reduce homogeneity in student activity within teams using RBL. We designated roles within each team based on students' personal commitments and interests, striving to create heterogeneous knowledge spectrums within teams. Role changes were not permitted during the semester. The project roles include 20 students each as administrators, developers, data managers, and content owners, managing team organization, development, data collection, and design respectively, with an additional 10 students focused on online marketing. The de facto team leader was the administrator, but we didn't formalize this to leave events unfolding organically, which as stated by Perrera could have a positive impact [27], [31]. The instructors were also involved in the role-play as stakeholders: they played the role of the future owner of the CMS system developed.

The semester, spanning 13 teaching weeks, was divided into four phases. At the end of each phase, which can be considered as project milestones, we provided feedback to students regarding their progress within the phase. Each phase had a specific main objective for both the team and individual roles. However, it was the responsibility of the students to define their detailed tasks, which also were subject to evaluation.

Although the instructors have access to the ticketing systems, and relied on the content of it, the scoring was done manually, based on subjective expert judgement. Students were required to use the ticketing system and its proper management was part of the grade. Team scores accounted for 25% of the points earned, which were the same for all members, while individual performance scores accounted for 75%. Each student prepared a personal report for each phase. The individual points were determined by their activity in the ticketing system, the completion and quality of their assignments, and the contents of their reports. The assignment point is subject to expert evaluation. The ticketing point should be more or less clearly derivable from the ticketing system data. Normally, the report point is closely related to both the ticketing and assignment points. Lastly, the team point should be the result of both individual performance and collaboration among the participants.

The project used the open-source ticketing system MantisBT. The relational database of the system provided a high degree of flexibility in data extraction. This system uses the usual structure of ticketing systems: the basic unit is the ticket, to which many fields suitable for classification, text comments and files can be attached. The time spent can be added as numerical information to the comments. A ticket, although containing a single specific person in charge, allows the work of different team members to be filed. The system also allows for the hierarchical linking of tickets and the definition and control of sub- and stage deadlines. Fig. 1 shows a simplified ticket management process through the state changes of a task. After formulating the problem to be solved, a new ticket is added. Once a responsible person has been assigned, the state changes to 'assigned'. The responsible person then indicates any comments and records the time spent in a note before closing the ticket. If there is a lack of information needed to solve the ticket, supplementary information can be queried from the reporter using the feedback state. If the available information is or becomes sufficient, the ticket can be resolved by the assigned person and returned to the submitter, who can then close or reopen it after testing. The tester, who can be the original reporter or another assignee, can also attach comments and time-tracking information during the process.

A detailed event log can be extracted from the ticket management system database, which can be analyzed to get a comprehensive picture of the activity of each team member. Over the semester, 90 users recorded around 20,000 events. The system distinguishes a total of 37 event types, which were grouped into six categories according to practical reasons, summarized in Table 11.

TABLE 1
EVENT CATEGORIES USED FOR GROUPING EVENT LOG RECORDS

Event Type	Description
NEW_BUG	Add a new ticket
BUG_ASSIGNED	Assigning a ticket to the assignee
BUG_RESOLVED	Set the ticket to solved status; wait for the test
BUG_CLOSED	Close ticket
BUGNOTE_ADDED	Adding a comment to the ticket. Comments also store the time spent, so it is possible that several participants are working on the same ticket assigned to a user. Bugnotes can also hold file attachments.
BUG_EDITED	Modify any of the ticket data in addition to the above

We have created a project for each student team in the system. The teams were not allowed to see each other's projects, they could only work on their own. The chosen system allows for a hierarchical grouping of projects, so each project was categorised under a project representing the seminar group. This allows for instructor-dependent analyzes and analyzes based on the characteristics of the seminar group, such as the number of teams in the course.

We calculated the Cumulative Grade Point Average (CGPA) for the participating students at the beginning of the semester. The CGPA is the overall average of a student's grades throughout their academic program. It is calculated by taking the grade points earned in all courses, multiplying each by the credit hours of the course, summing these values, and

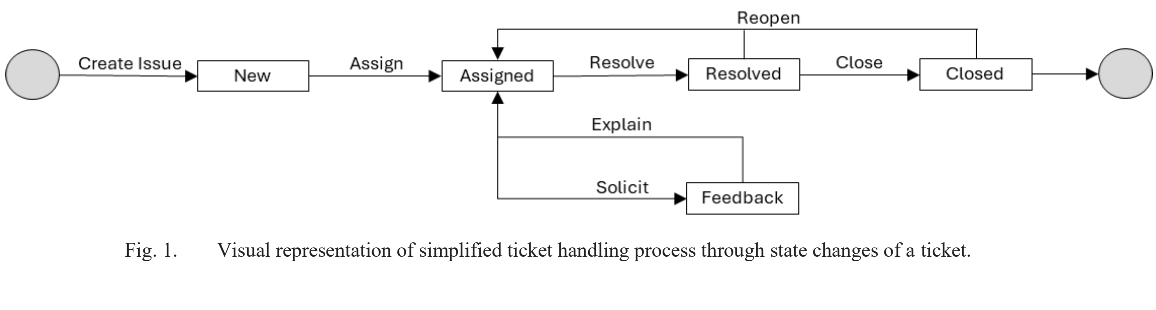


Fig. 1. Visual representation of simplified ticket handling process through state changes of a ticket.

dividing by the total number of credit hours completed. This measure provides a comprehensive overview of a student's academic performance. For engineering students, the CGPA may be a reliable predictor of final graduation performance, based on Adekitan and Salau's recent study [32]. We used this value to verify the adequacy of scores given through subjective evaluation.

V. Research Methods

The purpose of our research is to substantiate the empirical experiences of the course, implementing new solutions, and analyze the collected data to enhance the course content and evaluation system. The data collected from the ticketing system, along with the final grades and scores earned during the semester, form an event log, enabling not only exploratory statistical examination but also facilitating the analysis of temporal and sequential data.

After anonymizing and reducing the event categories (Table 1), the event log is prepared for examination. By using SQL queries, records from the event log can be extracted from the relational database of the ticketing system. We explored the collected data along three dimensions and derived further explanatory variables from the obtained data:

Temporal: Analyzing temporal aspects helps us understand how frequently students used the ticketing system, the evenness of activity distribution, and whether there are signs of expected real-time usage and indications of deviations from that pattern. To achieve this, we measure daily events and event types by role and collectively. Additionally, we conduct time-series analysis to uncover short-term and long-term seasonal effects.

Content: We examine how many times representatives of each role initiated events, what kind of content they recorded in the system, and how effectively they used the system for communication. The content dimension includes the received points, evaluations, and submitted reports. Our goal is to understand the behavioural patterns characteristic of each role and the students' attitudes towards tasks. For this purpose, beyond investigating averages and dispersion measures, we conduct dictionary-based sentiment analysis [33] on student reports using the PrecoSenti lexicons [34], [35], after lemmatizing the texts using Hunspell [36]. Primarily for methodological verification, we also perform sentiment analysis on the textual evaluations provided by the instructors, comparing the results with assigned scores. If we observe the expected correlation, it suggests that our analysis is correct, and the results obtained from the sentiment analysis of the students' reports are relevant as well.

Network: Collaborative learning is based on cooperation. We are interested in understanding, based on the data from the ticketing system, which group members were able to collaborate effectively. We aim to investigate whether weaker connections align with the experiences reported in the evaluations, or if they were simply characterized by different communication channels in those cases. To examine this, we conducted a network analysis following these considerations: two team members are connected if they worked on the same ticket. The relationships between two students were weighted by the frequency of their connections.

Our goal is to leverage the insights provided by the analyzes to better support the work of struggling students in the next iteration of the course, and ideally, to design a more motivating yet fair scoring system. To achieve this, we will compare the results collected from the temporal, content, and network aspects with the scoring outcomes using a correlation matrix. This approach will allow us to identify significant relationships and patterns, thereby informing improvements in our pedagogical strategies and assessment methods.

VI. Results

The semester lasted for 14 weeks with a holiday week in the middle (week 7) and was divided into four phases. Each of the four project phases concluded with a phase-ending week, during which students presented their results and received the tasks for the next phase. The number of daily recorded events throughout the semester can be seen on Fig. 2. During the semester, there was a one-week break starting on April 3, during which the activity level dropped to zero. While this is not inherently concerning, this low activity level persisted until the end of the following week. This phenomenon is likely attributed to the half-semester exam period.

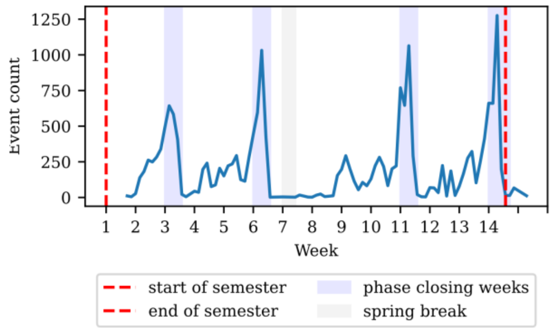


Fig. 2. The representation of the daily aggregated number of events. Four major milestones were designated during the semester, with the phase closing weeks indicated on the diagram (the closing presentations happened around the middle of the week). An increase in student activity can be observed as each phase closing week approaches, with activity peaking during these weeks.

We expected students to log their activities in real time. As deadlines approach in any project, motivation tends to increase, leading to a rise in the frequency of activities. Therefore, it was anticipated that activity levels would surge during phase-ending weeks. However, this should not overshadow the possibility that activities were entered into the system retroactively, solely to consider them during the scoring process. The event frequency curve shown in Fig. 2 suggests that this may have indeed occurred.

The daily activity divided by roles is depicted in Fig. 3. Remarkably, the Administrator role stands out in terms of activity, as these students recorded their activities in the ticketing system and closed them. Naturally, these two activities were more prominent during the phase-ending weeks. For the other roles, such a trend effect is less acceptable, ideally, their workload should be distributed more proportionally. Nevertheless, for every role, there are four major peaks during the phase-ending weeks, which undoubtedly put the Administrator responsible for finalization in an uncomfortable position.

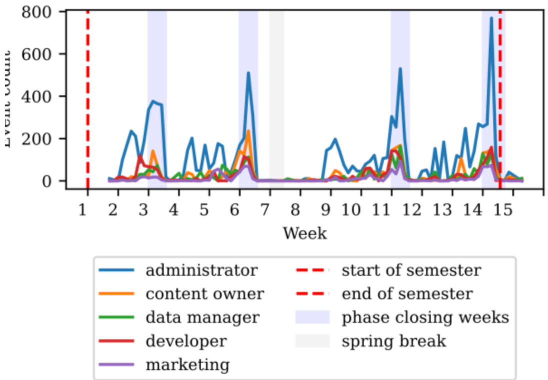


Fig. 3. Daily event count by roles, which accurately reflects the end-of-phase weeks.

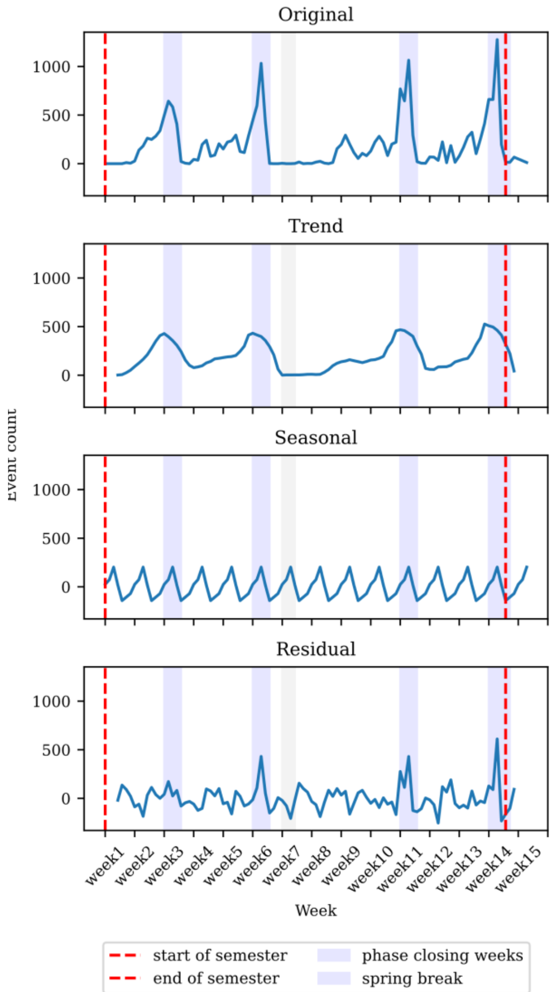


Fig. 4. Time series decomposition of daily event counts. The trend component shows the phases, while the seasonal component reflects the weekly repetition of classes.

To investigate the long- and short-term seasonal effects, the data set was analyzed using time series decomposition, the results of which are shown in Fig. 4. On the one hand, among the long-term trends, the aforementioned effect related to phase-locked weeks is clearly visible. On the other hand, among the short-term effects, it is also clear that a significant part of the activity is specifically linked to the weekly classes, although in fact there is no reason for this due to the organization of the training since the weekly exercises were weekly meetings without any task completion. The residual data series, stripped of trends and seasonality, also shows a spike in activity in the phase-out weeks.

The continuity of ticketing system usage is illustrated in Fig. 5, which provides information about active days, meaning how many students performed any activity in the system on a given day. The semester spanned 13 instructional weeks, covering 91 calendar days. The majority of students were active on fewer than a quarter of the possible days. This also suggests retroactive entry of activities. The figure also displays the distribution of active days by role. The average activity level of non-administrator role students is similar, though significant variations can be observed.

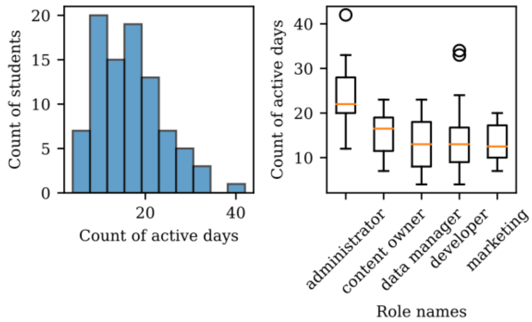


Fig. 5. Active days by students and roles. The majority of students were active at most twice a week during the semester. The most active role was that of the administrators, followed by the content owners, with the other roles having similar activity levels.

The low number of active days observed in Fig. 5 could also be attributed to the granularity of the tasks in the assignments. There is no consensus in the literature and practice regarding the ideal time requirements for tasks within an assignment. However, during the course, students were advised to work with relatively fine granularity, and ideally, the time requirement for a single assignment should not exceed one day. For instance, a task with a time requirement of 16 hours (calculated as four hours of work per day) could result in a perceived inactivity of 3 days. To determine this, we examine the reported time commitments by students, as shown in Fig. 6. The highest recorded time is approximately 100 hours, with an average of 44.3 hours per student and a high standard deviation of 22.1 hours. Since the total tracked time was not considered when determining the scores, the instructors did not focus on giving feedback regarding the lack of complete time recording. Thus, it is plausible that many students simply forgot to submit their time recordings, which is a common issue in real work environments as well.

Regarding the content created, apart from analyzing the temporal aspects, we also need to examine what was generated. Any ticketing system should be capable of reconstructing and presenting the completed work in a comprehensible manner, primarily through textual descriptions. This fulfilment is assessed through the analysis of the generated content in addition to the investigated events.

In summary, during the semester, students created 1954 tickets for their projects, to which they attached 4326 comments. In the specialized project designed for seeking support, they requested help in 156 cases, appending a total of 148 comments.

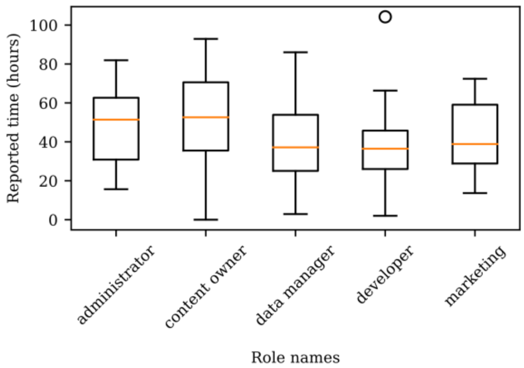


Fig. 6. Time reported by roles. According to the students' self-reported time logs, they spent a maximum of 60 hours on the course during the semester, which amounts to approximately 4 hours per

For the analysis of added textual content, we examined the length of content formulated in tickets and their associated comments. If the text is short, it can be assumed that it doesn't carry valuable information, and merely reviewing tickets and comments wouldn't yield more comprehensive insights into the workflow. The characteristics of log entries with content can be observed in Fig. 7.

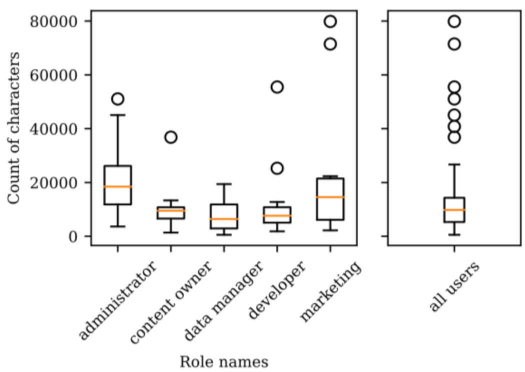


Fig. 7. Textual content added by roles and overall, including ticket descriptions, comments, and text content from attached files.

Throughout the semester, students provided insights into their achieved results in four reports corresponding to each phase. The submitted texts underwent dictionary-based sentiment analysis. In the first phase, students exhibited a positive attitude towards the task, with relatively high variability. In the second phase, the average sentiment measured in the reports continued in the third and fourth phases. Given the challenging nature of the tasks in the fourth phase, one might expect a further decrease in the observed sentiment in the reports.

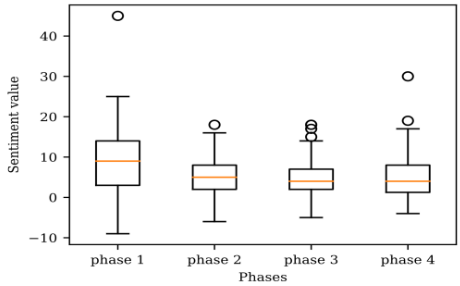


Fig. 8. Results of sentiment analysis of performance reports by students for each project phase.

However, the analysis did not indicate this, although there was a slight increase in variability. The results are summarized in Fig. 8.

The ticketing system is fundamentally designed to facilitate collaboration, making it suitable for successful application of network analysis tools. Since the five-member teams only worked within their own projects and the support project, we cannot speak of the emergence of a larger network. In terms of the entire ticketing system, the relationship graph is not connected. We consider two users to have a connection if they collaborated related to the same ticket. Within the project, the maximum achievable degree is equal to the team's size. As team sizes vary, the achieved degree is divided by the team size, resulting in a corrected degree. As shown in Fig. 9, half of the students worked together with all their teammates, but more than 10% left no trace of collaboration within the ticketing system. This could either have taken place on an external platform or not at all.

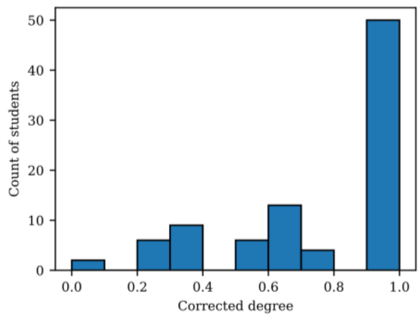


Fig. 9. Frequency of students with degrees corrected for team size. Nearly half of the students did not communicate with every teammate.

Network analysis can provide an additional dimension to characterize the roles. Consider Fig. 10, where we can observe the average weighted degrees calculated based on the connections established between the different roles. The figure shows which role collaborations were prominent: marketers typically collaborated with content owner role users, while developers collaborated with data managers.

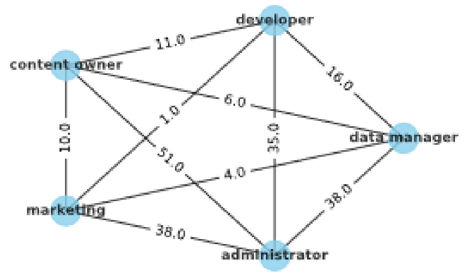
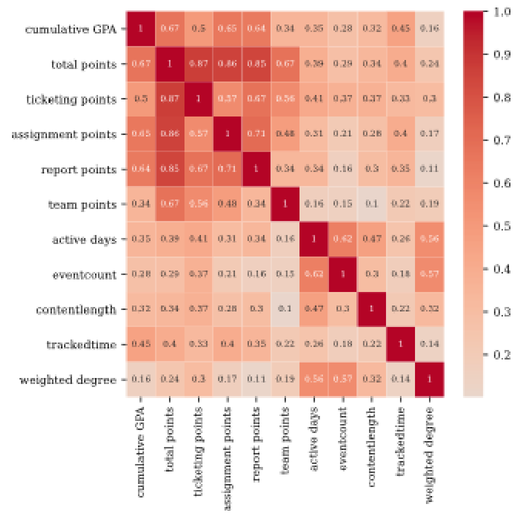


Fig. 10. Median of weighted degree between roles, based on the frequency of communication and collaboration.

One of the primary goals of this research is to propose a method for objectively grading the work of the students. This does not simply consist of evaluating the results as grades should reflect the management of the ticketing system and the whole process as well. During the examined semester, the metrics of the ticketing system played a marginal role in determining the points for this aspect. Due to the lack of benchmarking data, instructors primarily evaluated students' performance subjectively. Therefore, the grades assigned during the semester are not directly suitable for building a grading model. The distribution of points for the ticketing system management is skewed to the right (Fig. 11). This distribution shape can be attributed to the pilot nature of the course evaluation and the lack of previous experience (as it was the first year of the course). Evaluators might have leaned towards assigning more favourable scores to the students. In terms of the other components of the points, it can be said that while the distribution of points for assignments is closer to normal, the points for reports and particularly for teamwork are significantly high.

Improving the grading system requires an understanding of the details of the current subjective scoring. Fig. 12 shows the correlation matrix of our score variables and some of the measurements of the ticketing system. The total project score (total points) of the students has rather strong correlation with the cumulative grade point average (CGPA) from other courses, thus it is most likely that the subjective scoring managed to match the skill and effort of the students.

The correlation between the partial scores (ticketing points, assignment points, report points, team points) is relatively high as well, with the sole exception of the team points, since the other three focused on the individual. This means that even though these parts were graded separately both the quality of the work and the evaluation of the teachers stayed consistent.



Fig, 12. The correlation between the C GPA, total points received during the project course, the components of these points, and the extracted indicators.

The ticketing measurements are definitely not independent. The strongest connection is between the number of days a student was active on in the ticketing system (active days) and the events they generated in the system during this time (eventcount). These also have relatively strong correlations with the strength of the connection between the team members (weighted_degree). This variable was calculated based on the number of events which could be connected to other team members (e.g.: direct mentions, posts in the same task etc.) and the value was weighted based on the size of the team. It is important to note that this variable could be misleading as of course the ticketing system was not the only platform of communication between team members. The total length of text content created by a user (contentlength) and total time they reported spending on their tasks (trackedtime) on the other hand are only weakly related to the other variables. This seems reasonable as these are the only two variables which do not increase naturally the more granulated the activity is.

Comparing the scores with the measurements, it is natural that the ticketing point has the strongest correlation with each. The assignment point is close second, thus the better someone managed to keep track of their work, the more likely they managed to finish their tasks in time. The reports are similar as the more actual effort was put into the project the easier it is to write a good report about it. The measurements have very little connection with the team points, since these variables

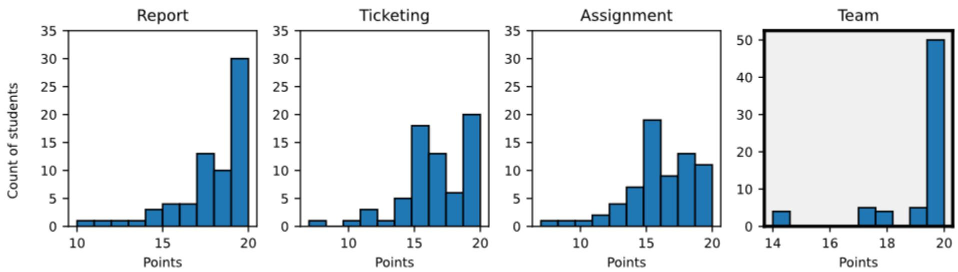


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Fig. 11. Frequency of points for individual and team performance, detailing points given for report, ticketing, assignment, and team contributions

measure the continuous activity, while team points were only awarded for the completion of the tasks.

VII. Discussion

We showed that the scoring system led to results which correlate with the students' grades from other courses. Thus, it is safe to assume that the results of the subjective scoring method represent the skill level and effort of the individuals. So, the decision-making process of the teachers is correct, and an objective approach can be implemented by finding the driving factors behind their decisions.

Based on the correlation matrix of the scores and the measured variables we can conclude that the teachers granted higher scores for more granulated activities and were less influenced by the total length of the content or the total time tracked.

The overall activity patterns of the students seem to be similar along the roles (with the exception of the administrator), even though they have vastly different tasks. This indicates that the team members tend to work together, and they are also influenced by each other's habits. However, the activity and behaviour of the individual roles tends to differ significantly, but the current measurements cannot show these differences. The GitHub activity of the developers was not included, nor did we consider the attached images. For example, the content owners usually work with screenshots and design plans, while the marketing tends to create documents in which they collect their findings. Thus, appropriate, automated scoring requires either the inclusion of different types of measurements or the targets for each role must be set separately. The data from version control systems may contain valuable additions for understanding the behavior of the developer and data manager roles, as highlighted by related studies [27], [28].

The event count and granularity along with the stored content allows us to examine the work process and team dynamic of the students. It is clearly visible what steps the students in different roles took to produce results which satisfy the requirements set by their tasks. The medians of these role-specific measurements can be used as a benchmark for the objective scoring limits in the next iteration of the course.

The course aims to prepare students for real-life scenarios where continuous work is expected. However, even the most prominent students tend to leave tasks to the last minute. This behaviour has a negative effect in the long term: tasks tend to pile up, overtime is often needed to meet deadlines, stress and lack of regularity results in health issues and usually leads to burnout. In terms of the course the teammates (especially the administrator) can end up in situations which are difficult to handle, since they might need someone else's work finished to start their own. Even though teaching students how to handle these kinds of conflicts is part of the course, reducing their numbers would still be beneficial. Thus, the new formative grading system should include aspects which reward continuous work and sanction the procrastination mentality.

To address the procrastination behaviour of the students, the ticketing system points can be spread out into weekly scores. The timestamps would already support this approach, but continuous feedback on whether the weekly input of someone was satisfactory or not could help with the motivation as well. Smaller blocks of scoring are also easier to automate, as students have a better understanding of their results, and it is easier for them to argue about it. This can either lead to the students' better understanding of their mistakes and overall improvement of their performance, or we could realize a potential mistake in the way the scores are calculated. Thanks to the steady workload, the activity of the students will be naturally granulated. Thus, they have more time to reflect on their decisions or to improve on a good idea. So, they will automatically focus on aspects which were rewarded by the subjective scoring of the teachers.

The use of a ticketing system is beneficial for trainers because it can provide a good picture of the actual value added by students working in a team, but this is only a side benefit: its main purpose is to facilitate productivity and communication. Thus, network characteristics are explicitly recommended to be considered and rewarded. Working in a group can have a positive influence on the performance of the individual, as people tend to push each other further. Based on the final projects and reports we assume that most teams worked together well, and members used different methods to communicate with each other constantly. However, students who had a higher weighted degree, that is those who communicated through the ticketing system as well, achieved higher scores. It is likely that having the communication documented exerted pressure on people to do a good job with their tasks, since having multiple unanswered comments and notices from other team members in a phase made it clear who was slacking. So, the more access instructors have to project related communication, the less likely it is that someone holds back the team.

So simply making the related communication visible for a figure of authority could improve overall performance. To address this issue in the next iteration of the course, we intend to provide a communication platform – preferably with transcript enabled VoIP options – which the teachers could access as well. By explaining to the students that this can help them in case of conflicts or if they forget to document important information in the ticketing system, we hope to turn this platform into their preferred tool without making it a requirement.

The success of data collection can be crucial for conducting other studies aimed at studying behavior. For example, if the system is completely transparent, it opens up the possibility for the application of peer grading [2], as well as for studying the confirmed interaction between emerging de facto leadership roles and team performance [31]. As observed, the ticketing system enables tracking of who most frequently delegates tasks, communicates with others, or resolves problems themselves, which can lead to insights about the leadership style of the administrator role and its impact on team dynamics.

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It is important to reduce the chance of conflict in the teams, since this kind of project requires creativity, and it works best when participants get into a flow state while working, which is significantly easier if they like the tasks. The reports showed a relatively positive attitude from the students throughout the semester. In a real work environment, the enthusiasm tends to drop by the end of the project, since by that time the creative processes are usually overtaken by the tedious final tasks. However, a real "passion project" brings satisfaction with every single step. We aim to create a learning environment in which students can experience this kind of feeling of success.

A flexible system is necessary as students' creativity should not be hindered by it in such a project course. Gamification and GBAF are great tools to include limitations while not reducing the enthusiasm of the participants [10]. The kind of role-playing aspect of the course can already be considered a type of gamification, but including challenges and competitions between teams could further improve the experience. The current course wraps up with the team presentations at the end of the last phase. Next time, we will give the teams an opportunity to vote for the best projects after everyone finished. Not only will we provide extra points for the teams with the most votes, we will also honor those who managed to vote for the best teams, since judging the quality of someone else's project is an important skill to develop as well. This feature could be implemented after the closure of the former phases as well.

VIII. Conclusion

We examined the data collected in the ticketing system throughout the semester of our experimental, group project course with the aim of rethinking the scoring system and overall improvement of the course material. It can be concluded that the ticketing system database can be a good starting point for the development of an objective scoring system, but further steps are needed to measure real activity. Objective scores have a better chance of being suitable for automated evaluation with the help of custom developed plugins. So not only are they fairer, but they can also reduce the workload of the teachers, who can use this additional capacity to personalize support for the teams.

Based on our findings, we have made the following recommendations to improve the course:

- The median of event count and granularity can be used as a benchmark for objective scoring limits, but the ticketing system points should also be granted separately for every week to discourage procrastination.
- Including a built-in platform for project related communication and emphasizing the importance of documenting thought processes can further improve transparency and allows better feedback from the instructors.
- Introducing competition through gamification can significantly improve engagement while also providing an incentive for students to familiarize themselves with the work and ideas of other teams.

Overall, after the next iteration of the course data from both approaches will be available, and it will be possible to compare the results. However, right now the positive influence of the above changes is yet to be verified, and they might introduce loopholes. Since the current subjective scoring produced acceptable results, we only plan to base about half of the point on objective – hopefully automatically calculated – criteria. The rest will allow us to be flexible and compensate for any unintended effect. The development process of this course will most likely see many more iterations, but the more data is collected, the better, statistically verified improvements can be made.

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